

Oct. 11, 1949.

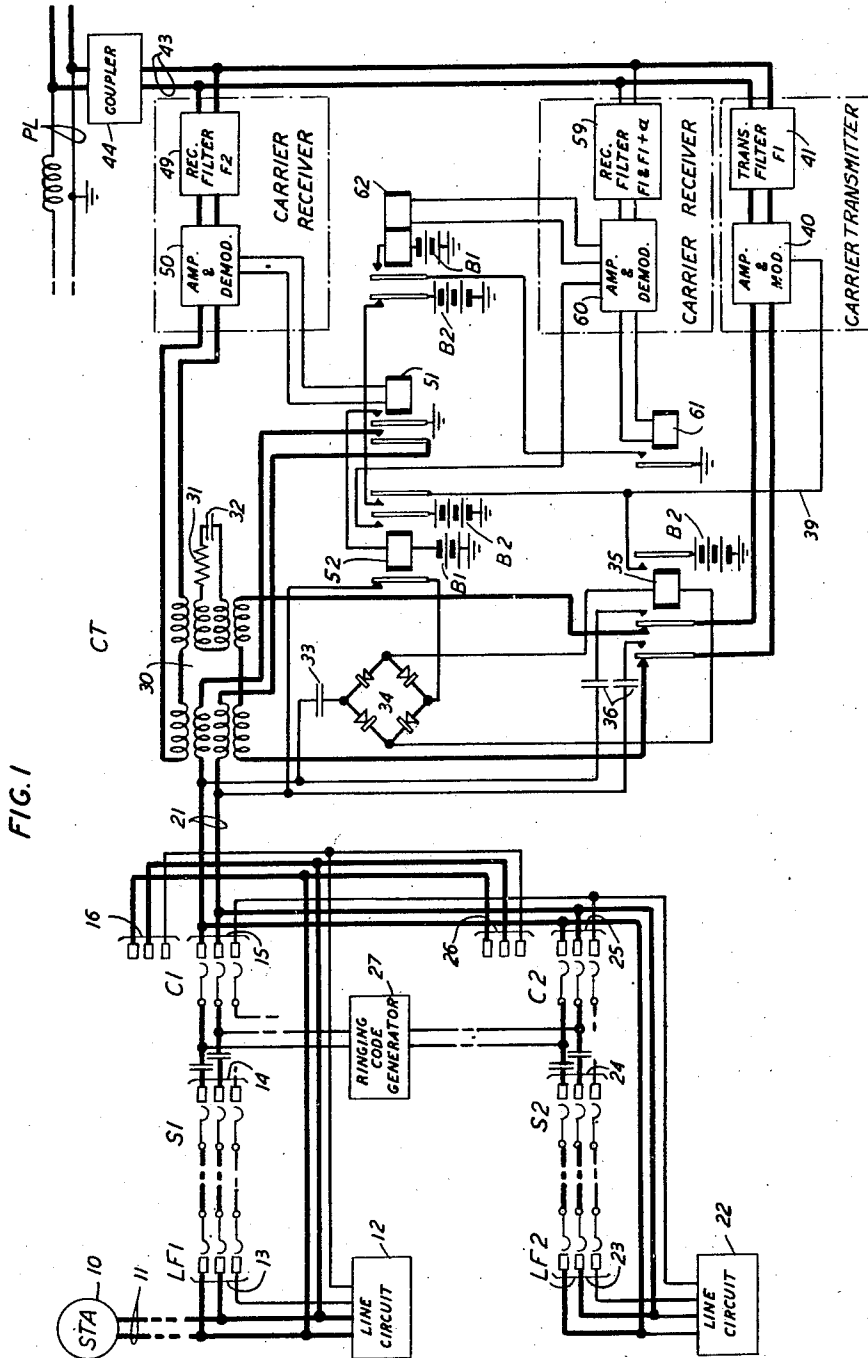
J. W. EMLING

2,484,211

POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

Filed Oct. 11, 1946

2 Sheets-Sheet 1



INVENTOR
J. W. EMLING
BY
R. O. Correll
ATTORNEY

Oct. 11, 1949.

J. W. EMLING

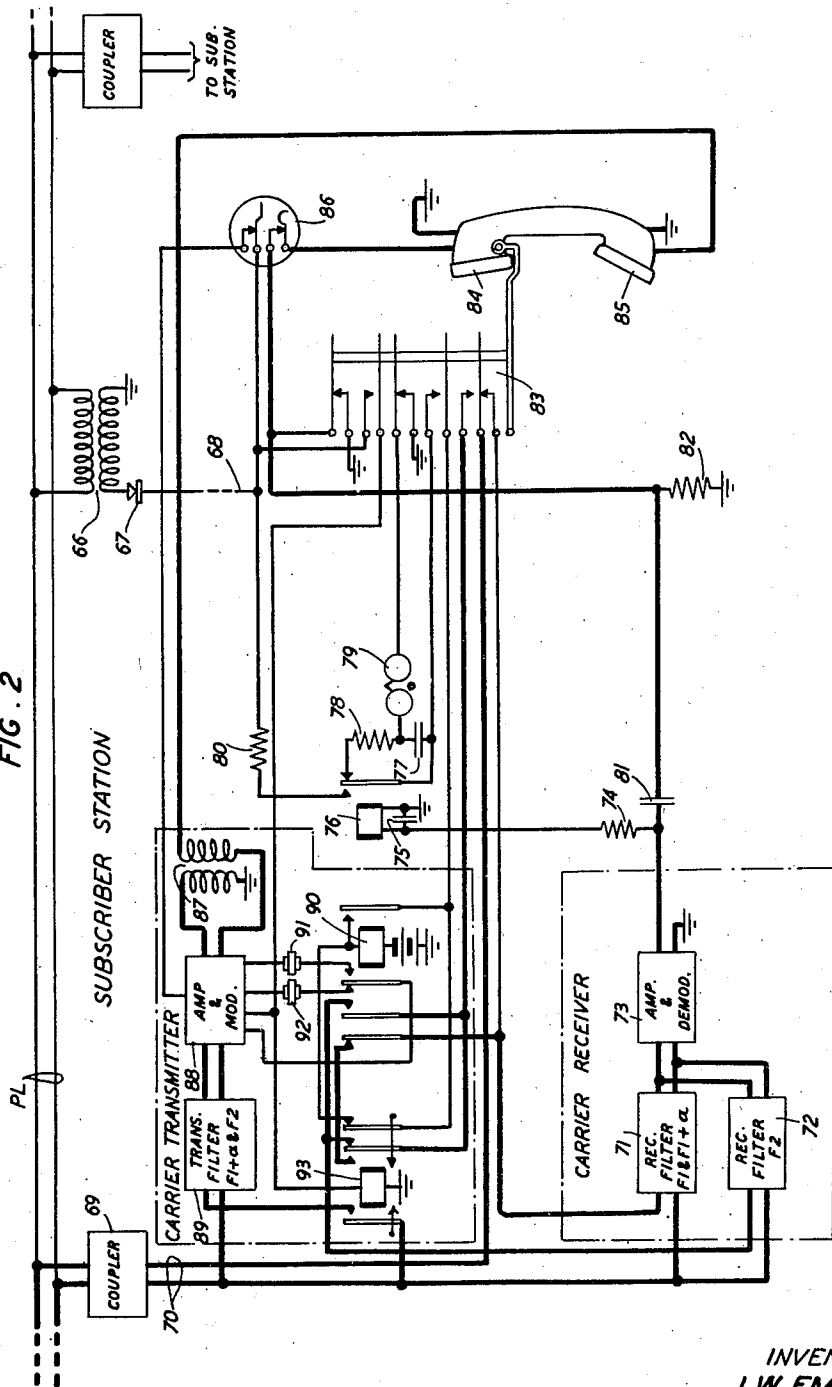
2,484,211

POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

Filed Oct. 11, 1946

2 Sheets-Sheet 2

FIG. 2



INVENTOR
J. W. EMLING
BY
R. O. Correll
ATTORNEY

UNITED STATES PATENT OFFICE

2,484,211

POWER LINE CARRIER FREQUENCY
TELEPHONE SYSTEMJohn W. Emling, Morristown, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application October 11, 1946, Serial No. 702,693

6 Claims. (Cl. 179—2.5)

1

2

This invention relates to communication systems and particularly to telephone systems including subscriber stations arranged for carrier current operation over a power transmission line.

Objects of the invention are the provision of carrier telephone service over a power transmission line including means for holding the associated line to the telephone central office on calls between telephone stations connected to the power line, the elimination of manual control means at these stations heretofore provided for use only on such calls, and in general the simplification and improvement of power line carrier telephone systems.

This invention is a telephone system comprising subscriber stations arranged for carrier current operation over a power transmission line to which they are connected, carrier terminal equipment being provided for connecting the power line to a telephone line terminating in a telephone central office. Carrier current of one frequency is used for transmitting over the power line, voice and signal currents to any one of the stations and carrier current of another frequency is used for transmitting voice and signal currents from any one of these stations. On a call between stations connected to the power line and utilizing the same carrier channel over the power line, the carrier transmitting and receiving frequencies are automatically interchanged at the calling station and a reverting call signal is transmitted to the carrier terminal to terminate the transmission of carrier current therefrom, this signal resulting from a beat between the carrier current transmitted from the carrier terminal equipment and the carrier current transmitted from the calling subscriber station.

A clear and complete description of the invention will be facilitated by considering a system in which the invention and its features are embodied, such a system being represented schematically in the drawing. The invention is, however, not limited in its application to the system shown but is generally applicable to telephone systems. The invention is also applicable to radio transmission and carrier transmission systems over media other than power transmission lines.

The drawing, which consists of two figures, represents an automatic telephone exchange serving subscriber stations some of which are arranged for carrier operation over a power transmission line.

Fig. 1 indicates a conventional automatic telephone exchange comprising a subscriber station 10, subscriber lines 11 and 21 and line circuits

12 and 22, line finder switches LF1 and LF2, selector switches S1 and S2, connector switches C1 and C2, a carrier terminal equipment CT individual to the line 21, and a power transmission line PL to which the carrier terminal equipment CT is coupled by coupling means 44.

Fig. 2 shows one of a plurality of subscriber stations connected to, and arranged for carrier current operation over, the power line PL.

The subscriber station 10 is of the usual type provided for use on lines terminating in an automatic central office and includes a dial or impulse sender (not shown) for use in selectively controlling the switches through which desired connections are established. The line finder, selector and connector switches are of the two motion step-by-step type, each of the line finder and selector switches being represented in the drawings by a set of brushes and a single set of terminals and each of the connector switches being represented by a set of brushes and two sets of terminals. The relays and other apparatus associated with the line finder, selector and connector switches are represented by broken lines. Reference may be had to "Automatic Telephony" by Smith and Campbell, 2nd Edition, pages 53 to 65 for a detailed description of the structure of two-motion step-by-step switches and their operation when used as selectors and connectors. Reference may be had to the patent to R. L. Stokely 1,799,654, granted April 7, 1931, for disclosure of a line circuit and a line finder of the step-by-step type. The ringing code generator 27 comprises a source of ringing current and means for interrupting the ringing supply conductors as required to produce a plurality of different ringing codes for signaling subscriber stations. Reference may be had to the patent to Duguid No. 2,225,907, granted December 24, 1940, for disclosure of such a ringing code generator and to the patent to Koechling No. 2,289,503, granted July 14, 1942, for a detailed disclosure of a connector switch arranged for ten party code ringing.

The carrier terminal equipment CT, power line PL and the carrier telephone subscriber stations of Fig. 2 constitute a power line carrier telephone system similar generally to the system disclosed in the copending application of R. C. Edson and J. W. Emling, Serial No. 653,254, filed March 9, 1946, now U. S. Patent No. 2,481,915, granted Sept. 13, 1949, to which application reference may be had for discussion of the carrier frequencies suitable for use in such systems and for a more complete disclosure of the coupling means be-

3

tween the power line and the carrier receivers and transmitters and details of the carrier equipment CT and carrier telephone stations. The power line PL is one phase of a power transmission line and serves a plurality of power and light customers, some of which are equipped for carrier telephone service as shown in Fig. 2.

The carrier terminal station or equipment unit CT comprises a hybrid coil or group of transformer windings 30 arranged to transmit signal and voice currents to and from line 21. The resistor 31 and condenser 32 constitute a network connected to the middle right pair of windings to balance the line 21. The upper pair of windings receive voice frequency currents from a carrier receiver comprising the amplifier-demodulator 50; and the lowest pair of windings transmit voice frequency currents from line 21 to the input circuit of a carrier transmitter comprising the oscillator-modulator-amplifier 40. The power line PL is connected through coupling means 44 and conductors 43 to the carrier receiver comprising receiving band filter 49 and the associated amplifier-demodulator 50, to another carrier receiver comprising receiving band filter 59 and amplifier-demodulator 60, and to the carrier transmitter comprising transmitting band filter 41 and oscillator-modulator-amplifier 40. The amplifier-demodulators 50 and 60 and the oscillator-modulator-amplifier 40 may be of any known suitable type. The oscillator-modulator 40 is tuned to transmit through filter 41 carrier current of a frequency F' , as modulated by either signaling or voice currents incoming over line 21. The amplifier-demodulator 50 receives, through filter 49 from the power line PL, carrier current of a frequency F' modulated by voice and signal currents from any one of the carrier telephone stations connected to the power line PL. The amplifier-demodulator 60 is tuned by band filter 59 to receive carrier current of frequency F' transmitted from oscillator-modulator-amplifier 40 and to receive carrier current of a frequency $(F'+a)$ where a is a low frequency, for instance, 200 cycles per second, $(F'+a)$ being the frequency of the carrier which is transmitted from the calling one of the carrier telephone stations on a reverting call. The transmitting and receiving filters 41 and 49 transmit the voice frequency sidebands in addition to the carrier frequency. Relay 61 is energized in response to the reception and demodulation of carrier current of frequency $(F'+a)$ and relay 62 is tuned to be operated by the beat frequency between the frequency F' of the carrier current transmitted from oscillator-modulator-amplifier 40 and the carrier frequency $(F'+a)$ transmitted from any of the carrier stations.

The carrier terminal equipment CT further comprises relay 35 controlled by ringing current incoming over line 21 to energize the oscillator-modulator-amplifier 40 and thereby transmit impulses of carrier current corresponding to the ringing code received by relay 35 from line 21. The carrier terminal equipment CT further comprises relays 51 and 52 controlled by amplifier-demodulator 50 responsive to signals transmitted over the power line by carrier current of frequency F' from any of the carrier stations. The functions of each of the relays is hereinafter described in detail. The sources of energy for operating the relays and for energizing the amplifiers, modulators and demodulators is represented as being batteries B1 and B2 but may be sup-

4

plied by rectifying the output of a transformer which receives its energy from the power line PL.

Each of the carrier telephone subscriber stations is similar to the one shown in Fig. 2 and is connected through individual coupling means 69 to the power line PL. Each station comprises a carrier receiver, a carrier transmitter, a telephone receiver 84 and transmitter 85 combined in a handset which normally rests on the receiver hook 83, a dial 86 for controlling automatic switches in the telephone central office to establish desired connections, a relay 76 and a ringer 79. The carrier receiver comprises a receiving band filter 71 tuned to pass the carrier frequencies F' and $(F'+a)$, a receiving band filter 72 tuned to pass the carrier frequency F' and amplifier-demodulator apparatus 73. The carrier transmitter comprises oscillator-modulator-amplifier apparatus 88, a transmitting band filter 89 for transmitting voice modulated carrier current of frequency $(F'+a)$ and also current of frequency F' , a frequency control relay 90, oscillator crystals 91 and 92, and a transmitter control relay 93 for connecting the output conductors of filter 89 to the power line. The transmitting and receiving filters transmit the voice frequency sidebands in addition to the carrier frequency. The oscillator-modulator-amplifier apparatus, conventionally illustrated as a rectangle 88, includes an oscillator whose frequency is controlled by the one or the other of the crystals 91, 92 depending upon the operated or unoperated condition of relay 90 together with suitable amplifying and modulating means whereby the carrier waves are modulated at times in accordance with voice waves applied through transformer 87. The oscillator may be any suitable and well-known crystal controlled oscillator such as found shown in Cady's book on "Piezoelectricity," first edition, 1946, published by McGraw-Hill Book Company, Incorporated, pages 495 and 499, Taylor Patent 1,639,817, dated August 23, 1927 or Nicholson Patent 2,212,845, dated August 27, 1940. The one or the other of the two crystals 91 or 92 is switched into circuit to establish the carrier frequency at one value or another at different times as herein described. Modulation may be accomplished in any suitable well-known manner by means of any one of many well-known modulating circuits of which the following examples are given: Van der Bijl Patent 1,350,752, August 24, 1920 and Heising Patents 1,343,562, June 15, 1920 and 1,560,054, November 11, 1925. Lack Patent 2,218,200, October 10, 1940 discloses a suitable combined oscillator and modulator which could readily be arranged for shift from one crystal to another by relay 93. Devices of this kind are considered to be so well known in the art that they need no further description. The power supply for the amplifier, modulator and demodulator apparatus includes a rectifier 67 and a transformer 66, connected to the power line either directly or through an intermediate transformer. Other transformer windings may provide the energy for heating the filaments of vacuum tubes and supply whatever other operating potentials are required. No reverting call key is provided since the transmission of a reverting call signal is automatically effected.

Call from station 10 to a carrier telephone station

Assume that a call is initiated at station 10, that the line 11 is connected by a line finder LF1 to a selector S1, that the selector S1 is selectively

controlled by dial impulses from station 10 to select a group of trunks and an idle trunk therein associated with a connector C1, and that the connector C1 is selectively controlled by dial impulses from station 10 to select the line 21. Assume further that the line 21 is idle when tested by the connector C1, that a ringing code is selected responsive to dial impulses from station 10, and that the selected ringing code is transmitted through the brushes of connector C1 over the conductors of line 21 through condenser 33, rectifier 34, and a back contact of relay 52 to the winding of relay 35. Relay 35 is thereby operatively energized during each ringing interval of the ringing code transmitted over line 21. The operation of relay 35 connects the positive pole of battery B2 to conductor 39 to energize the oscillator-modulator-amplifier 40, disconnects the lower pair of windings of hybrid coil 30 from the input conductors of oscillator-modulator-amplifier 40, and connects these conductors through condensers 36 to the conductors of line 21; whereby the ringing current incoming over line 21 modulates the carrier current transmitted through filter 41, conductors 43 and coupler 44 over the power line PL to each of the carrier telephone stations connected to the power line.

At each of the carrier telephone subscriber stations the ringing current modulated carrier of frequency F1 incoming over power line PL is transmitted through a coupler 69, conductors 70, and a normally closed contact of the springs controlled by receiver hook 83, through receiving band filter 71 to the input circuit of amplifier-demodulator 73. The output circuit of amplifier-demodulator 73 includes resistor 74 and the winding of relay 76; and relay 76 is operated responsive to carrier current incoming over the power line. A condenser 75, connected in parallel with the winding of relay 76, renders this relay somewhat slow in operating so as to tend to prevent its operation responsive to interfering currents such as static. The output conductor of modulator 73 is further connected to condenser 81 thence through the off-normal contacts of dial 86 and telephone receiver 84 in parallel with resistor 82. While the telephone handset is in normal position on hook 83, receiver 84 and resistor 82 are short-circuited at a back contact of the springs controlled by hook 83. The operation of relay 76 closes a circuit from the lower winding of transformer 66 through rectifier 67, conductor 68, resistor 80, front contact of relay 76, condenser 77, and through the windings of ringer 79 to ground at a back contact of the springs controlled by receiver hook 83. The windings of ringer 79 are thereby energized while condenser 77 is charging. Since the incoming carrier current of frequency F1 is modulated by the frequency of the ringing current transmitted over line 21 from the central office, relay 76 is alternately operated and released at the ringing current frequency (for instance 16 cycles per second) during each ringing interval of the ringing code. Each time relay 76 releases, condenser 77 discharges through resistor 78; and each time relay 76 reoperates, condenser 77 is charged through ringer 79. Thus, the ringer 79 at each of the carrier telephone subscriber stations associated with power line PL is actuated in accordance with the ringing code of the particular station which is being called.

When the handset is removed from the hook 83 at the called station, the circuit through ringer 79 is opened, the short circuit across the receiver

84 is opened, and the positive potential supply conductor 68 is connected to the winding of relay 93 and to the oscillator-modulator-amplifier 88, operating relay 93 and energizing the amplifier-modulator 88. Relay 93 is somewhat slow in operating to allow time for relay 90 to operate if relay 76 is operated at the time the handset is removed, as is the case at the calling station on a reverting call as hereinafter described. However, on the call now being described, relay 76 is not operated at the called station when the handset is removed because at this time there is no carrier current of frequency F2 being transmitted over the power line, so that relay 90 is not operated; and the operation of relay 93 disconnects the winding of relay 90 from the armature of relay 76, thereby to prevent the operation of relay 90 on this call from station 10. Since relay 90 is normal, the oscillator crystal 92 is included in the oscillating circuit of oscillator-modulator 88, whereby carrier current of frequency F2 is generated and transmitted through filter 89, a front contact of relay 93, conductors 70 and coupler 69, over power line PL to each of the other carrier stations and to the carrier terminal equipment CT. The carrier current of frequency F2 does not reach the demodulator 73 at each of the other carrier subscriber stations because, at each of these stations, the input circuit of filter 72 is open as long as the handset is in normal position on hook 83. But at the carrier terminal equipment CT, the carrier current of frequency F2 passes through coupler 44, conductors 43 and receiving band filter 49 to the input circuit of amplifier-demodulator 50 causing the operative energization of the winding of relay 51. The operation of relay 51 closes a circuit for operating slow-to-release relay 52 and closes a bridge, consisting of the left middle pair of windings of hybrid coil 30, a cross line 21 to trip the ringing in the connector C1. The opening of the ringing circuit and closing of the talking connection through connector C1 is effected in usual and well-known manner. The operation of relay 52 opens the circuit connection between the winding of relay 35 and line 21, and connects the positive pole of battery B2 to the amplifier-demodulator 60 and to the oscillator-modulator-amplifier 40. The energization of the amplifier-demodulator 60 performs no useful function on this call; but the energization of oscillator-modulator-amplifier 40 effects the transmission of carrier current of frequency F1 through filter 41 over the power line PL to each of the carrier stations, causing the energization of relay 76 at each of these stations. The voice currents incoming over line 21 from the calling station 10 are transmitted through hybrid coil 30 to the input circuit of modulator-amplifier 40 to modulate the carrier current of frequency F1 transmitted over the power line to the carrier stations. At the called station, the voice current output of amplifier-demodulator 73 is transmitted through the receiver 84, but at the other carrier stations, the receiver is short-circuited at a contact of the receiver hook springs. The transmitter 85 of the handset of the called station generates voice currents which are transmitted through coil 87 to the input circuit of modulator-amplifier 88 to modulate the carrier current of frequency F2 which is being transmitted over the power line. The voice modulated carrier current of frequency F2 passes through filter 49 to demodulator 50; and the voice currents are transmitted through hybrid coil 30 over line 21

through the connector, selector and line finder switches, over line 11 to the calling station 10. Two-way conversation now takes place, over the established connection including power line PL between the calling and called station.

When the handset is replaced on hook 83 of the called station, receiver 84 is short-circuited, relay 93 is released, and the oscillator-modulator-amplifier 88 is deenergized, terminating the transmission of carrier current of frequency F2 over the power line and thereby causing the successive release of relays 51 and 52 of the carrier terminal equipment CT. The release of relay 51 opens the bridge across line 21 thereby releasing the answering supervisory relay (not shown) in the connector C1. The release of relay 52 disconnects battery B2 from oscillator-modulator-amplifier 40 to terminate the transmission of the carrier current of frequency F1 over the power line, thereby releasing relay 76 at each of the carrier stations. When the subscriber at the calling station 10 releases the connection, the connector C1, selector S1 and line finder LF1 are restored to normal in usual and well-known manner.

Call from carrier telephone station

Assume next that the handset is removed from hook 83 at one of the carrier telephone stations connected to power line PL to initiate a call. Relay 93 is thereby operated; relay 90 remains normal and the oscillator-modulator-amplifier 88 is energized to transmit carrier current of frequency F2 over power line PL causing the successive operation of relays 51 and 52 of carrier terminal equipment CT. At each of the other carrier subscriber stations, the carrier current of frequency F2 transmitted over line PL from the calling carrier station is ineffective to operate relay 76 because the input conductors 70 are normally connected across the input conductors of filter 71 and are not normally connected across the input conductors of filter 72. The operation of relay 51 of carrier equipment CT closes the bridge across line 21 whereby the line relay (not shown) of line circuit 22 is operated to start an idle line finder such as LF2 to connect with the calling line, and line 21 is thus connected through the brushes of line finder LF2 to the associated selector S2. The operation of relay 52 opens the circuit connection between relay 35 and line 21 and connects battery B2 to oscillator-modulator-amplifier 40 and to amplifier-demodulator 60. The energization of oscillator-modulator-amplifier 40 effects the transmission of carrier current of frequency F1 over power line PL. Dial tone is transmitted from selector S2 over line 21 through hybrid coil 30 to the input of modulator 40 to modulate the carrier current of frequency F1 being transmitted over the power line to the carrier telephone stations. The carrier current of frequency F1 effects the operation of relay 76 at each of the carrier stations; and, at the calling carrier station, the dial tone is transmitted through the receiver 84 to indicate that the dialing of the number of the telephone station with which connection is desired may be started. The calling party thereupon dials the directory number of the called station. When the dial is moved off normal, the receiver 84 is disconnected from amplifier-demodulator 73; and, as the dial returns to normal, the impulse contacts of the dial modulate the carrier current of frequency F2 being transmitted from the oscillator-modulator-amplifier 88. Each dial impulse thus transmitted from the calling station

over the power line causes the release and reoperation of relay 51. Each release and reoperation of relay 51, responsive to dial impulses, opens and closes the bridge across line 21 thereby repeating the dial impulses to selectively control the operation of selector S2 and a connector C2 to extend the connection to the called line and to select the ringing code required for signaling the called station. Since relay 52 is slow to release, it remains operated during the response of relay 51 to dial impulses.

Assume first that the called station is not one of the carrier stations connected to the power line PL. When the call is answered, the connector C2 opens the ringing circuit and closes the talking circuit in usual and well-known manner; and talking currents are transmitted through hybrid coil 30 and over the power line in both directions. The connection is under the control of the calling carrier telephone station; and, when the handset of this station is restored to normal condition on the hook 83, relay 93 is released and the oscillator-modulator-amplifier 88 is deenergized, terminating the transmission of carrier current of frequency F2 and thereby causing the successive release of relays 51 and 52 of the carrier terminal equipment CT. The release of relay 51 opens the bridge across line 21 and the release of relay 52 deenergizes the oscillator-modulator-amplifier 40. The opening of the bridge across line 21 causes the release of the line relay (not shown) of the connector C2 and return of the selector S2 and line finder LF2 to normal in usual manner. The connector C2 is also restored to normal in usual manner as soon as both the calling and called stations have released the connection.

Assume next that the call initiated at a carrier telephone subscriber station as above described is a reverting call, that is a call to another subscriber station connected to the power line PL. In such a case, the connector C2 finds the called line 21 busy when it makes the busy test, and a busy tone is thereupon transmitted from the connector, through selector S2, and line finder LF2, over line 21, through hybrid coil 30, modulator-amplifier 40, filter 41, power line PL, filter 71, amplifier-demodulator 73 and condenser 81 to telephone receiver 84 at the calling station. The connector C2 is arranged to make a reverting call test and, if the call is a reverting call, the line finder LF2 and selector S2 are restored to normal when the calling subscriber hangs up; but the connector C2 remains connected to the line 21 to ring the called station. Reference may be had to the patent to H. Hovland 1,849,087, granted March 15, 1932 for disclosure of a connector arranged to make the aforementioned reverting call test. Upon hearing the busy tone transmitted from connector C2, the calling subscriber hangs the handset on the hook 83. Relay 93 releases and the oscillator-modulator-amplifier 88 is deenergized to terminate the transmission of carrier current of frequency F2 over the power line and thus release relay 51 of the carrier terminal equipment CT. The release of relay 51 opens the bridge across the conductors of line 21; the line finder LF2 and selector S2 are restored to normal, and the connector C2 is operated to close the ringing circuit and apply the ringing code of the called station to the conductors of line 21. The release of relay 51 also causes the release of relay 52 but the energization of the ringing relay 35 responsive to ringing current received over line 21 effects the energization

of the oscillator-modulator-amplifier 40 to transmit ringing current modulated carrier current of frequency F_1 over the power line PL. At each of the carrier telephone subscriber stations the relay 76 responds to the ringing current and causes actuation of the ringer 79 according to the ringing code of the called station. When the called subscriber answers by removing the handset from hook 83, relay 93 is operated and the amplifier-modulator 88 is energized to transmit carrier current over the power line. Since at this time there is no carrier current of frequency F_2 being received over the power line, relay 76 is not energized at the called station and relay 90 does not operate. With relay 90 normal, oscillator crystal 92 is connected in the oscillator circuit of modulator 88 so that the carrier current transmitted therefrom is of frequency F_2 ; and with relay 93 operated and relay 90 normal, the input circuit of filter 71 is closed and the input circuit of filter 72 is open, so that the amplifier-demodulator 73 is tuned to receive carrier current of frequency F_1 and frequency $(F_1 + a)$. The transmission of carrier current of frequency F_2 over the power line PL from the called station effects the reoperation of relays 51 and 52 of the carrier terminal equipment CT. The operation of relay 51 closes the bridge across the conductors of line 21 to trip ringing and to operate the answering supervisory relay (not shown) of the connector C2 in usual manner. The operation of relay 52 connects the positive pole of battery B2 to energize the oscillator-modulator-amplifier 40 and also to energize the amplifier-demodulator 60. The energization of the oscillator-modulator-amplifier 40 effects the transmission of carrier current of frequency F_1 over the power line to energize relay 76 at each of the carrier telephone stations.

When the operation of the ringers at the carrier telephone stations ceases due to answer of the call at the called station, the calling party removes the handset from receiver hook 83 thereby opening the connection between input conductors 70 and the input conductors of filter 71 and connecting input conductors 70 to the input conductors of filter 72. Since, at this time, carrier current of frequency F_2 is being transmitted over power line PL from the called station, relay 76 is operated at the calling station and removal of the receiver closes a circuit through the winding of relay 90; which circuit includes the outer right back contact of relay 93, a normally open contact of the springs controlled by hook 83, front contact of relay 76, resistor 80, conductor 68, rectifier 67 and the lower winding of transformer 66. Relay 90 is thus operatively energized before the slow-to-operate relay 93 operates, and relay 90 locks independent of relay 93. The operation of relay 90 includes the oscillator crystal 91 instead of crystal 92 in the oscillating circuit of modulator 88 whereby carrier current of frequency $(F_1 + a)$ is transmitted from the calling station instead of carrier current of frequency F_2 . With both of relays 90 and 93 operated at the calling station, the input circuit of filter 72 is closed and the input circuit of filter 71 is open; so that voice modulated carrier current of frequency F_2 incoming from the called station is transmitted to the receiver 84. The carrier current of frequency $(F_1 + a)$ transmitted over the power line from the calling station passes through filter 59 at the carrier terminal to amplifier-demodulator 60 thus causing the operation of relay 61. The carrier current of frequency $(F_1 + a)$ incoming over the power line from the calling

station and the carrier current of frequency F_1 transmitted over the power line from oscillator-modulator-amplifier 40 produces a beat of a cycles per second—for instance, 200 cycles per second. Relay 62 is tuned to operatively respond to energization of its right winding by current of the beat frequency. When operated, relay 62 is held operated by its left winding under the control of relay 61. The operation of relay 62 disconnects battery B2 from oscillator-modulator-amplifier 40 to terminate the transmission of carrier current of frequency F_1 therefrom while conversation is taking place between the calling and called stations. It is to be noted that this arrangement has the advantage that if the receiver is removed at some carrier station other than the calling or called carrier station while a call other than a reverting call is in progress, the transmission of carrier current of frequency F_1 from the carrier terminal equipment will be resumed as soon as the receiver is replaced at the interfering station.

If the calling subscriber hangs up first, relay 93 releases and oscillator-modulator-amplifier 88 is deenergized, whereby the transmission of carrier current of frequency $(F_1 + a)$ from the calling station is terminated, causing the release of relay 61 and 62 of carrier terminal equipment CT and the release of relay 76 at each of the carrier stations not involved in the call described. The release of relay 61 connects battery B2 to oscillator-modulator-amplifier 40 whereby carrier current of frequency F_1 is now transmitted from the carrier terminal equipment CT over the power line causing the reoperation of relay 76 at each of the carrier stations. Relay 51 is held operated by the carrier current of frequency F_2 being transmitted over the power line from the called subscriber station. When the called subscriber disconnects, the oscillator-modulator-amplifier 88 thereat is deenergized terminating the transmission carrier current of frequency F_2 over the power line, releasing relays 51 and 52 of the carrier terminal equipment CT. The release of relay 51 opens the bridge across the conductors of line 21 thereby causing the release of the connector C2 and the release of relay 52 again connects the winding of relay 35 across line 21 for response to ringing current on a succeeding call.

If the called subscriber hangs up first, the transmission of carrier current of frequency F_2 therefrom is terminated causing the release of relay 51 of the carrier terminal equipment CT and causing the release of relays 76 and 90 at the calling subscriber's station. The release of relay 90 reconnects the oscillating crystal 92 in the oscillating circuit of modulator 88 in place of the crystal 91 whereby the transmission of carrier current of frequency $(F_1 + a)$ is terminated and the transmission of carrier current of frequency F_2 is initiated at the calling subscriber's station. Relay 51 of the carrier terminal equipment CT is thus reoperated before the slow-to-release relay 52 has released so as to hold the central office connection until both of the subscriber's have disconnected. When the calling subscriber hangs up, relay 90 releases and the oscillator-modulator-amplifier 88 is deenergized at the calling station.

If the called subscriber fails to answer on a reverting call, the ringer at each of the carrier stations is actuated by the ringing current until the receiver is removed from the switch-hook at some one of the stations. When the receiver is replaced at the subscriber station, the carrier

11

terminal equipment CT is restored to normal as well as the carrier equipment at the answering station.

What is claimed is:

1. In a telephone system, a telephone line, a power transmission line, a carrier terminal station interconnecting said lines, a plurality of telephone subscriber stations connected to said power line, said carrier terminal station comprising a carrier current transmitter for transmitting over the power line carrier current of a first frequency, a first carrier receiver for receiving over the power line carrier current of a second frequency and a second carrier receiver for receiving over the power line carrier current of said first frequency and carrier current of a third frequency, each of said subscriber stations comprising carrier current transmitting and receiving means arranged to selectively transmit over the power line carrier current of said second or said third frequencies and to receive over the power line carrier current of all of said carrier frequencies, means at said carrier terminal station for energizing the carrier transmitter thereat responsive to carrier current of said second frequency incoming over said power line, and means at said carrier terminal station operatively responsive to the beat between the carrier current of said first frequency transmitted by the carrier transmitter at said carrier terminal station and the carrier current of said third frequency received over the power line from the calling station on a reverting call for disabling the carrier transmitter at the carrier terminal station.

2. In a telephone system, a telephone line, a power transmission line, a carrier terminal station interconnecting said lines, a plurality of telephone subscriber stations connected to said power line, said carrier terminal station comprising a normally deenergized carrier transmitter tuned to transmit carrier current of a first frequency, each of said subscriber stations comprising a carrier transmitter and means for tuning the transmitter to transmit carrier current of a second frequency on calls over said telephone line, to transmit carrier current of said second frequency on incoming reverting calls and to transmit carrier current of a third frequency on outgoing reverting calls, each of said subscriber stations further comprising a carrier receiver tuned at times to receive carrier current of said first and third frequencies and tuned at times to receive carrier current of said second frequency, said carrier terminal station further comprising a first carrier receiver tuned to receive carrier current of said second frequency, means operated responsive to the receipt of carrier current of said second frequency by said first carrier receiver for energizing the carrier transmitter at said carrier terminal station, a second carrier receiver tuned to receive carrier current of said first and third frequencies, and means tuned to operatively respond to the beat between said first and third frequencies when carrier current of both said first and third frequencies is being received by said second carrier receiver, the operation of said last-named means being effective to deenergize the carrier transmitter at said carrier terminal station and to prevent the energization of said transmitter as long as carrier current of said third frequency is being received by said second carrier receiver.

3. In a telephone system, a telephone line, a power transmission line, a carrier terminal station interconnecting said lines for telephone communication, and a plurality of telephone sub-

12

scriber stations connected to said power line, each of said subscriber stations comprising a carrier current transmitter to selectively transmit over said power line voice frequency modulated carrier current of either one of two carrier frequencies, said terminal station comprising a carrier current transmitter tuned to transmit carrier current of a third carrier frequency, a first carrier current receiver tuned to receive voice frequency modulated carrier current of a first one of said two carrier frequencies, a second carrier receiver at said terminal station tuned to receive carrier current of the other of said two frequencies and carrier current of said third frequency, means controlled by said first carrier receiver for energizing the carrier current transmitter at said terminal station, and means controlled by said second carrier receiver at said terminal station responsive to simultaneously receiving carrier current of said other of said two frequencies and carrier current of said third carrier frequency for deenergizing the carrier transmitter at said terminal station and for maintaining said deenergization as long as carrier current of said other of said two frequencies is being transmitted over said power line, each of said subscriber stations further comprising a carrier current receiver selectively tunable to receive carrier current of said first one of said two frequencies or to receive carrier current of said other of said two frequencies and carrier current of said third frequency, and means effective at times responsive to carrier current of said first one of said two frequencies incoming over said power line for tuning the carrier transmitter thereat to transmit carrier current of said other of said two frequencies and for tuning said carrier receiver to receive carrier current of said first one of said two frequencies.

4. In a telephone system comprising a dial subscriber telephone line, a power transmission line, a carrier current terminal equipment interconnecting said lines, and a plurality of carrier telephone subscriber stations connected to said power line, a carrier current transmitter in said carrier terminal equipment for transmitting carrier current of a first frequency over said power line, carrier current transmitting means at each of said carrier stations for transmitting carrier current of a second frequency or carrier current of a third frequency over said power line, a first carrier receiving means in said carrier terminal equipment tuned to receive carrier current of said second frequency from said power line, a second carrier receiving means in said carrier terminal equipment tuned to receive carrier current of said first and third frequencies, means responsive to carrier current of said second frequency incoming over said power line to said first carrier receiving means for energizing the carrier current transmitter of said carrier terminal equipment and said second carrier receiving means, control means tuned to the beat frequency between said first and third frequencies for deenergizing the carrier current transmitter of said equipment, and means for maintaining the deenergization of the carrier current transmitter of said equipment as long as carrier current of said third frequency is being received by said second carrier receiving means.

5. In a telephone system comprising a dial subscriber telephone line, a power transmission line, a carrier current terminal equipment interconnecting said lines, and a plurality of carrier telephone subscriber stations connected to said

13

power line, a carrier current transmitter in said carrier terminal equipment for transmitting carrier current of a first frequency over said power line, carrier current transmitting means at each of said carrier stations for transmitting carrier current of a second frequency or carrier current of a third frequency over said power line, a first carrier receiving means in said carrier terminal equipment tuned to receive carrier current of said second frequency from said power line, a second carrier receiving means in said carrier terminal equipment tuned to receive carrier current of said first and third frequencies, means responsive to carrier current of said second frequency incoming over said power line to said first carrier receiving means for energizing the carrier current transmitter of said carrier terminal equipment and said second carrier receiving means, control means tuned to the beat frequency between said first and third frequencies for deenergizing the carrier current transmitter of said equipment, means for maintaining the deenergization of the carrier current transmitter of said equipment as long as carrier current of said third frequency is being received by said second carrier receiving means, and carrier current receiving means at each of said carrier subscriber stations normally tuned to receive carrier current of said first and third frequencies and tunable to receive carrier current of said second frequency.

6. In a telephone system comprising a dial subscriber telephone line, a power transmission line, a carrier current terminal equipment interconnecting said lines, and a plurality of carrier telephone subscriber stations connected to said power line, a carrier current transmitter in said carrier terminal equipment for transmitting carrier current of a first frequency over said power line, carrier current transmitting means at each of said carrier stations for transmitting carrier current of a second frequency or carrier current of a third frequency over said power line, a first carrier receiving means in said carrier terminal

14

equipment tuned to receive carrier current of said second frequency from said power line, a second carrier receiving means in said carrier terminal equipment tuned to receive carrier current of said first and third frequencies, means responsive to carrier current of said second frequency incoming over said power line to said first carrier receiving means for energizing the carrier current transmitter of said carrier terminal equipment and said second carrier receiving means, control means tuned to the beat frequency between said first and third frequencies for deenergizing the carrier current transmitter of said equipment, means for maintaining the deenergization of the carrier current transmitter of said equipment as long as carrier current of said third frequency is being received by said second carrier receiving means, carrier current receiving means at each of said carrier subscriber stations normally tuned to receive carrier current of said first and third frequencies and tunable to receive carrier current of said second frequency, and means at each of said carrier subscriber stations effective at times responsive to carrier current of said second frequency incoming over said power line for tuning the carrier current transmitting means thereat to transmit carrier current of said third frequency and for tuning the carrier current receiving means thereat to receive carrier current of said second frequency incoming over said power line.

JOHN W. EMLING.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,773,613	Clark	Aug. 19, 1930
2,289,048	Sandalls, Jr.	July 7, 1942
2,294,129	Purrington	Aug. 25, 1942
2,294,905	Honaman	Sept. 8, 1942