July 7, 1942. G. SANDALLS, JR 2,289,048

POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

Filed June 19, 1941 3 Sheets-Sheet 1

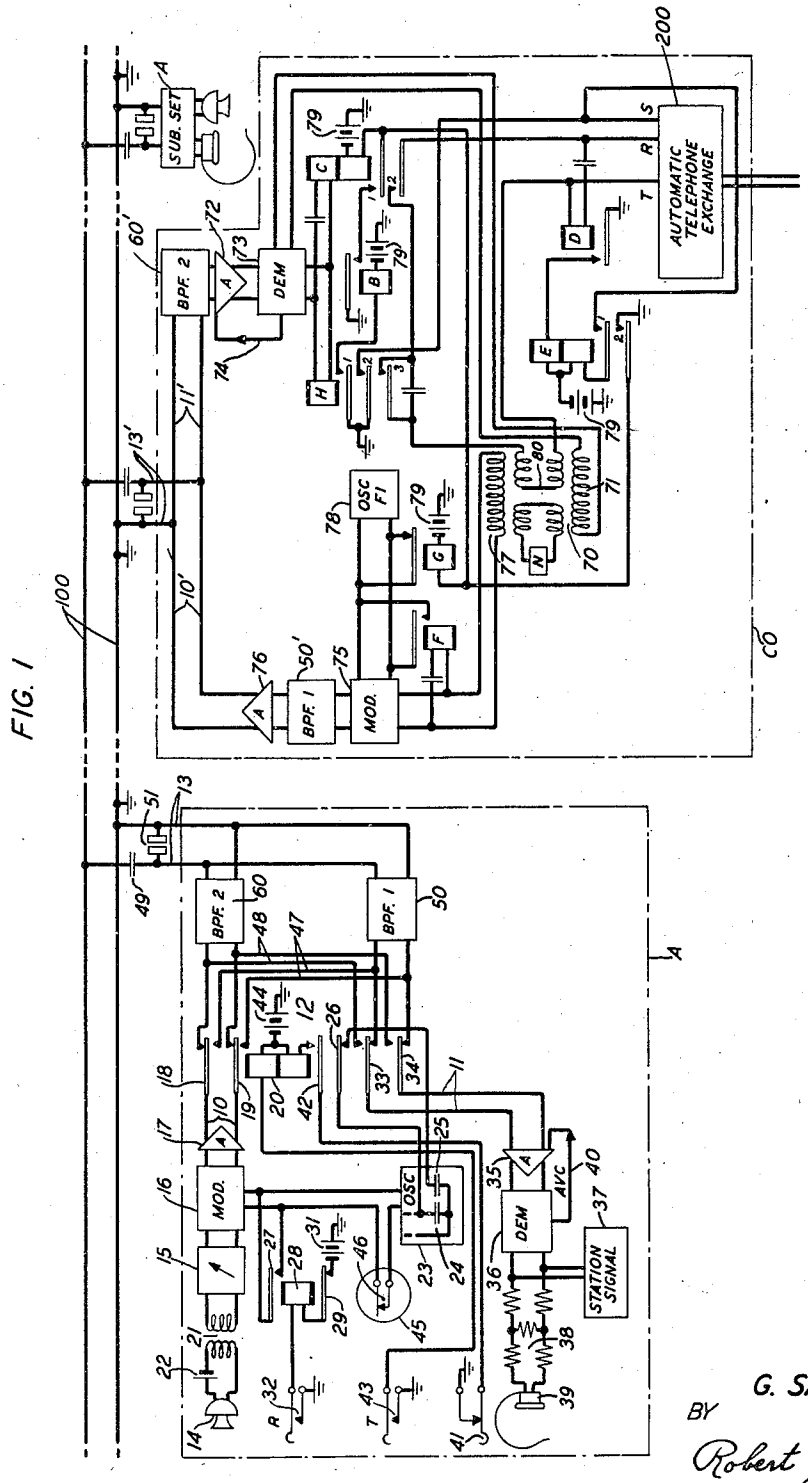

FIG. 1

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Filed June 19, 1941 3 Sheets-Sheet 2

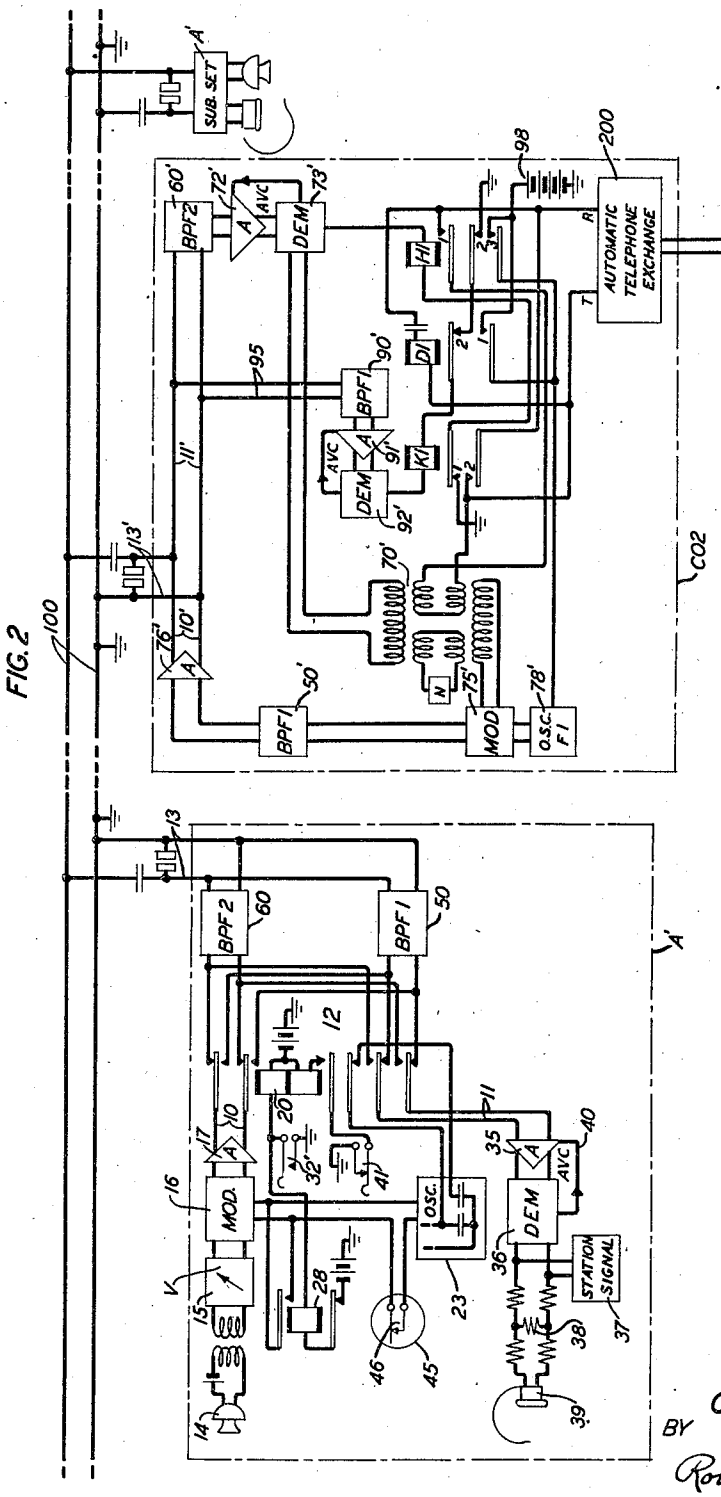

FIG. 2

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Filed June 19, 1941 3 Sheets-Sheet 3

FIG. 3

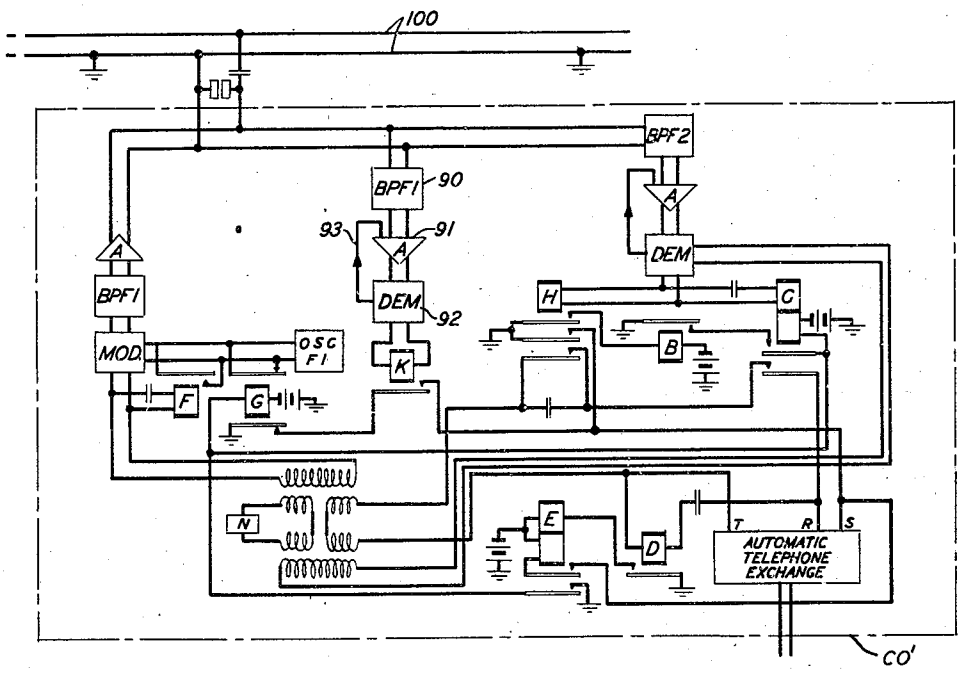
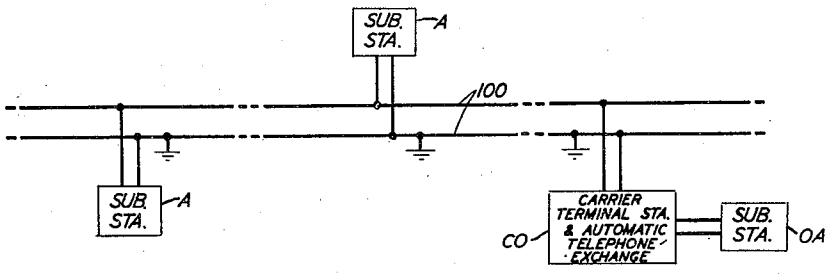


FIG. 4



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Patented July 7, 1942 2,289,048

UNITED STATES PATENT OFFICE

2,289,048

POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

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Application June 19, 1941, Serial No. 398,765

7 Claims. (Cl. 179—2.5)

This invention relates to electric wave transmission systems and, more particularly, to a carrier frequency telephone system.

An object of the invention is to improve telephone communication over a transmission line and, more specifically, over a power line.

A further object is to provide a power line carrier frequency telephone system in which telephone stations coupled to the power line are enabled to establish and maintain a connection directly with one another, and in which the telephone stations are enabled to connect with telephone stations outside of the power line system through an automatic telephone exchange or office.

In accordance with this invention, a power line telephone system is arranged to include a plurality of telephone stations coupled to the power line and adapted to signal and to communicate directly with one another on high frequency or carrier waves over the power line. The power line telephone system is connected with an automatic telephone exchange or office through a suitable converting or translating circuit adapted to translate a signal pulse modulated carrier wave into relay and/or switch actuating pulses, and to demodulate an audio frequency modulated carrier wave to provide the audio frequency currents for transmission over a conventional or voice frequency telephone system that correspond to the sound waves developed at a telephone station on the power line; and to modulate audio frequency current and signal pulses originating in the voice frequency telephone system onto a high frequency or carrier wave for transmission to the power line telephone system. The translating or converting circuit for connecting the power line telephone system and the outside telephone system may be located at the automatic telephone exchange, or, in a suitable case, may be located at a point along the power line and be connected with the automatic telephone exchange over a suitable voice frequency path.

Telephone communication, that is, signaling and conversation, takes place on two high frequency electric waves which, for convenience of description, will be denominated hereafter as carrier waves of high frequency F1 and F2. Calls made directly between telephone stations on the power line may be referred to as local or reverting calls. During such a reverting call, circuit conditions are established at the central office to prevent intrusion on the call from the central office. In making a reverting call, the calling party signals the called party in accordance with the preassigned signaling code for the system on one of the high frequency waves, for example, on carrier wave F1. Each station is normally in condition to receive such signals. After the called party has answered, the calling party transmits on the high frequency wave F1 used for signaling and receives on the other high frequency, that is, on carrier wave F2. The called party receives on the carrier wave F1 and transmits on the other high frequency wave. Each station, of course, is provided with a transmitting circuit and a receiving circuit for modulating the signal and voice frequency currents on the high frequency wave used for transmitting and for demodulating the incoming modulated high frequency wave.

In making a call through the automatic telephone exchange to a party not on the power line, the calling party establishes connection with the exchange by transmitting a signal pulse of high frequency, for example, carrier wave F2. Upon hearing dial tone, which is transmitted to the calling station on the high frequency wave F1, the calling party operates his calling dial or impulsing device to modulate the high frequency wave F2 in accordance with the dial pulses corresponding to the number dialed. The pulse modulated carrier wave is demodulated in the converting circuit and the dial pulses actuate the switches at the telephone exchange to establish the desired connection in well-known manner. Conversation between the calling and the called parties is on the carrier waves F1 and F2 between the converting circuit and the power line telephone station, and is at voice frequency between the converting circuit and the called party.

A more complete understanding of the invention will be derived from the detailed description that follows taken in conjunction with the accompanying drawings, wherein:

Fig. 1 illustrates a power line carrier frequency telephone system embodying the invention;

Fig. 2 illustrates a modification of the telephone system of Fig. 1;

Fig. 3 illustrates a modification of the central office arrangement of the telephone system of Fig. 1; and

Fig. 4 illustrates in broad outline the nature of the telephone system embodying the invention shown in detail in Figs. 1, 2 and 3.

Fig. 1 shows a power line carrier frequency telephone system comprising a line 100 primarily adapted for the transmission and distribution of low frequency high voltage electric power and

simultaneously used for high frequency or carrier wave telephony. A plurality of telephone stations A, two of which are shown and only one in detail, and a central office CO for the telephone stations, are coupled to the power line. The latter is shown as a single phase line one of whose wires is grounded, but it may be, of course, an insulated single phase line, or comprise a pair of phase wires of a multiphase system or other power line. Although only one telephone station is shown in detail, it will be understood that each of the telephone stations is the same and operates in a manner similar to that to be specifically described. Fig. 4 illustrates in a more general manner the arrangement contemplated by the invention. The telephone station OA represents a subscriber station of a telephone system served by the central office CO, but not connected to the power line or included in the power line telephone system as are stations A. Connection may be established, however, between the stations A and OA through the central office as will be evident from what follows.

Description of power line telephone station, Fig. 1

The telephone station A comprises a high frequency transmitting circuit 10, a high frequency receiving circuit 11, a switching and filter circuit 12, and a coupling line 13. The transmitting circuit comprises a transmitter or microphone 14, a volume limiter or gain adjusting device 15, a modulator 16 and an output amplifier 17, and terminates at the armatures 18, 19 of the circuit switching relay 20. The transmitter, which may be of the granular carbon type, is coupled to the device 15 by the transformer 21 and is connected in series with the transformer primary winding and a source 22 of talking current. The modulator 16 may be of any suitable type employing either electron discharge devices, or variable resistance devices such as copper—copper oxide rectifier units. An oscillator 23 is associated with the modulator and is adapted to generate the high frequency or carrier waves F1 and F2 for signaling and talking or transmitting purposes. The oscillator may comprise an electron discharge device circuit whose oscillation frequency determining circuit includes a pair of condensers 24, 25 connected, for example, in parallel. Condenser 25 is adapted to be removed from the circuit by the opening of the contact associated with the armature 26 of the relay 20. With condenser 24 only in the oscillator frequency determining circuit, the oscillation generated would be, for example, the high frequency F1. With both condensers in the circuit the wave generated would be the high frequency F2. The armature 27 and associated normally open lower contact of the relay or interrupter 28 are connected across the oscillator output. The interrupter 28 is adapted to vibrate at a suitable low frequency, for example, 20 cycles per second, and is provided with a lower armature 29 and associated normally closed lower contact connected through current source or battery 31 to ground. When the normally open key or pushbutton 32 is closed, an obvious circuit is closed for the energizing of the interrupter.

The receiving circuit is connected to the lower armatures 33, 34 of the relay 20, and comprises an amplifier 35, a demodulator 36, station signaling means 37, an attenuator network 38 and a telephone receiver 39. If desired, an automatic volume control connection 40 between the demodulator and amplifier may be provided to maintain the demodulator output at a preassigned level during receiving. The switchhook 41 is connected to the armature 42 of relay 20 and its associated normally open contact spring is connected to ground. The contact spring and switchhook are shown in engagement inasmuch as the receiver 39 is shown removed from the switchhook. A normally open key or push-button 43 is connected through the upper winding of relay 20 to one terminal of the battery or other source of current 44. The other and lower winding of relay 20 is connected between the battery 44 and the contact associated with the armature 42. A calling dial or impulse sending device 45, comprising a pair of pulsing springs 46, is connected in the circuit between the oscillator 23 and the modulator 16 for a purpose to be brought out more in detail hereinafter.

The circuit 12 is a part of the transmitting and receiving circuit and comprises a pair of band-pass filters 50, 60. The filter 50 is adapted selectively to transmit either or both side-bands of the modulated high frequency or carrier wave F1, and the filter 60 is adapted selectively to transmit either or both side-bands of the modulated high frequency or carrier wave F2. Each filter is connected between the coupling line 13 and a pair of normally closed contacts associated with the relay 20, those of the filter 50 being the lower contacts associated with the armatures 33, 34 and those of the filter 60 being the upper contacts associated with the armatures 18, 19. Cross-connections 47 connect the filter 50 to the normally open lower contacts of armatures 18, 1' and cross-connections 48 connect the filter 60 t the normally open upper contacts of armature: 33, 34.

The coupling circuit 13 comprises a pair of conductors, one of which is connected directly to the grounded wire of the power line and the other of which is connected through a condenser 49 to the non-grounded wire. If an insulated single phase power line or a pair of phase wires of a multiphase line are involved, a condenser should be connected in each coupling conductor. Instead of connecting the telephone station to the power line through a coupling condenser or condensers, the power distribution transformer located at the subscriber's premises could be employed for coupling purposes. In any event, a suitable protector 51 should be included in the coupling circuit to protect the subscriber and the station equipment against the hazards of high voltage arising on the power line.

Call between two power line telephone stations Fig. 1

The operation of the system in the making of a local or reverting call, that is, a call between two telephone stations on the power line, will now be described. Prior to the initiation of the call, the receiver 39 will be on the hook 41. Although not shown, it will be evident to the skilled in the art that additional switch contacts could be associated with the switchhook 41 and circuit connections provided so that, when the receiver is on the switchhook, the talking current circuit for transmitter 14 and the power supply circuit for the amplifiers 15 and 17 and the oscillator 23 would be interrupted, and so that, when the receiver is removed from the switchhook, the talking current circuit for the transmitter 14 would be closed and also the circuit for the supply of power to the amplifiers 15 and 17 and the oscil-

lator 23, and to the modulator 16 if the latter is of the vacuum tube type. The receiving circuit amplifier 35, however, and the demodulator 36, if of the power consuming type, would be energized at all times so that the station would be in condition to receive incoming signaling pulses for operation of the station signaling means 37, and so that a party on the line could ascertain if the system was in use by placing his receiver to his ear while holding the switchhook down. As shown in the drawings, the telephone station is in condition for receiving on carrier wave F1 and for transmitting on carrier wave F2.

Let it be assumed that the power line is not being used for telephonic transmission by another party or parties on the line and that the calling party is ready to initiate his call, that is, he has removed the receiver 39 from the hook 41. Closure of the key 43 completes an obvious circuit for the upper winding of relay 20 which locks up through its lower winding and armature 42. The filter 50 is connected through the connections 47 to the armatures 18, 19 and, hence, to the transmitting circuit 10, and the filter 60 is connected through connections 48 to the armatures 33, 34 and, hence, to the receiving circuit 11. The armature 26 is disengaged from its associated contact to remove condenser 25 from the oscillator's frequency determining circuit. The oscillator delivers a high frequency F1 to the modulator and through the filter 50, to the power line. The calling party then depresses or pushes key 32 the number of times and in accordance with the code prescribed for the power line telephone system to signal the desired station to operate the interrupter 28. This causes armature 27 to vibrate in association with its normally open contact to modulate the carrier wave supplied to the modulator. The carrier wave is modulated at the signaling rate, is transmitted through the filter 50 to the power line and passes over the latter to all of the stations. At each telephone station, the incoming modulated carrier wave F1 is transmitted by the filter 50 to the receiving circuit, is amplified in amplifier 35, demodulated by demodulator 36 and operates the station signaling means 37. In answering, the called party removes his receiver from its switchhook and the called station circuit is the same as was that of the calling station before the key 43 was depressed, that is, the called station is arranged to transmit on the carrier wave F2 and to receive on the carrier wave F1. When the called party answers, the calling party talks into the transmitter 14, the audio frequency currents corresponding to the sound waves acting on the transmitter that are developed in the transformer 21 are suitably amplified in the device 15 and transmitted to the modulator, to modulate the carrier wave F1 in accordance therewith. The modulated carrier wave passes through the output amplifier 17 and the filter 50 to the power line and over the latter to the called station. Since the called station transmits on the carrier wave F2, transmission incoming to the calling station will comprise a modulated carrier wave F2 which is transmitted through the filter 60 to the receiving circuit. The incoming wave is amplified in the amplifier 35, demodulated by the demodulator 36, and the demodulation components transmitted through the network 38 to the telephone receiver 39. The network 38 is provided to equalize for the lower transmission level required for listening compared to that required for operation of the station signaling means 37. When the conversation has terminated, the replacing of the receiver on the switchhook results in the deenergization of the relay 20 as a result of the removal of ground at the switchhook and the restoration of the station circuit to its original condition in which it is adapted to receive on the carrier wave F1.

Description of power line system central office, Fig. 1

Before describing the manner in which a call may be made from a telephone station on the power line telephone system to a telephone station of another or a general telephone system through an automatic exchange or central office, the circuit arrangement and equipment at the central office CO will be described. The central office circuit functions in general to translate or convert carrier current supervision and dialing into common battery signals suitable for actuating any conventional step-by-step, crossbar or all-relay dial equipment indicated generally at 200, and, also, to demodulate the modulated carrier wave incoming from the power line and to transmit a modulated carrier wave to the power line.

The central office comprises a transmitting circuit 10' and a receiving circuit 11' coupled to the power line through a coupling circuit 13' and coupled to the machine switching equipment and circuit 200 through the hybrid coil 70. The receiving circuit comprises a band-pass filter 60', adapted to transmit one or both side-bands of the modulated carrier wave F2 originating at a telephone station A, an amplifier 72 and a demodulator 73. An automatic volume control circuit 74 may be included to maintain constant the level of the signals at the output of the demodulator. The output of the demodulator 73 is connected with the lower winding 71 of the hybrid coil. The transmitting circuit comprises a modulator 75, a band-pass filter 50', adapted to transmit one or both side-bands of the modulated carrier wave F1, and an output amplifier 76. The modulator input is connected with the upper winding 77 of the hybrid coil and, also, with an oscillator 78 constituting a source of the high frequency or carrier wave F1 whose output is normally shorted by the normally closed contact set associated with the relay G. Relays B, C, D, E, F, G, H and their associated circuit controlling contacts are provided for purposes that will become apparent from the further description hereinafter. A common source 79 of energizing current for relays B, C, E and G is included in the central office.

Call between power line telephone station and the central office, Fig. 1

Let it be assumed that the subscriber at a station A on the power line wishes to make a call through the central office. As in the case of a reverting call or call local to the power line, removal of the receiver from its hook energizes the amplifiers and oscillator in the transmitting circuit, and the carrier wave F2 is applied to the power line through filter 60. The carrier wave is transmitted by the filter 60' at the central office to the amplifier 72 and demodulator 73 and energizes relay H whose contact sets 1, 2, 3 close. Closure of contact set 1 of relay H completes an obvious energizing circuit for relay B whose associated contact set closes. Closure of contact set 2 of relay H places ground on sleeve lead S causing the line terminal to test busy so long as the calling party maintains the connection with the central office. Closure of contact set 3 of

relay H through hybrid coil winding 80 prepares a metallic circuit between the tip and ring conductors T, R of the line circuit. After removing the receiver 39 from its hook, the calling party operates his signaling key 32 to operate the interrupter 28. The carrier wave F2 is modulated at a low frequency rate. The modulated carrier wave is received at the central office, is amplified and demodulated, and the low frequency demodulation component energizes the relay C. The associated normally open contact sets 1, 2 of relay C close. Relay C locks up over a circuit comprising ground, current source 79, lower winding and contact set 1 of relay C, contact set of relay B, to ground. Closure of contact set 2 of relay C completes the metallic circuit between the tip and ring conductors T, R causing the line relay to operate and the line finder to seize the line. Closure of contact set 1 of relay C also completes an energizing circuit for relay G: ground, source 79, relay G, contact set 1 of relay C, contact set of relay B, ground. This removes the short circuit on the oscillator 78 whereby the carrier wave F1 is applied to the power line through the modulator, filter 50' and amplifier 76. This carrier wave is modulated by dial tone from the first selector or link supplied to the modulator through the hybrid coil.

Upon hearing the dial tone, the calling party releases the signaling key 32, and proceeds to operate his calling dial 45 in well-known manner, interrupting the oscillator output as a result of the break-and-make of impulse springs 46 and thereby modulating the carrier wave F2 in accordance with the dial pulses. Relay H follows the dial pulses, releasing and momentarily interrupting the line circuit loop for each break of the dial impulse springs. The desired connection is established with the outside called party through the pulse operated switches of circuit 200 in well-known manner. At the conclusion of the outgoing call, when the calling party disconnects by restoring his receiver to its hook, the relays H, B, C and G release and the central office circuit is restored to its original condition.

In carrying on conversation with the called party, the power line telephone subscriber transmits on the carrier wave F2 and receives on the carrier wave F1. At the central office, the modulated carrier wave F2 is demodulated, and the audio frequency components corresponding to the sound waves developed at the power line subscriber's transmitter 14, are transmitted through the windings 71 and 80 of the hybrid coil and the tip and ring conductors to the called party. The audio frequency currents originating with the called party and incoming to the central office are transmitted over the tip and ring conductors and through the hybrid coil windings 80 and 77 to the modulator 75 in which they are modulated on the carrier wave F1. The modulated carrier wave is transmitted to the power line and over the latter to the station A, and through the filter 50 and receiving circuit 11 thereat to the subscriber's demodulating equipment and receiver.

On a call incoming to the central office for a telephone station on the power line, the operation is as follows: Ringing current from the link or connector energizes relay D. Closure of its normally open contact set completes an obvious circuit for the upper winding of relay E. The latter, through its lower winding and its contact set 1, locks up to the sleeve conductor S and completes, through its contact set 2, obvious energizing circuits for relays G and C. The normally closed contact set of relay G opens to remove the short circuit on oscillator 78 and carrier wave F1 is delivered to the oscillator; operation of relay C closes the latter's normally open contact set 2 to complete the tip and ring conductors circuit through the winding 80 of the hybrid coil. The relay F, adapted to respond to a low frequency alternating current, e. g., of the order of 20 cycles per second, is operated by ringing current supplied to it through the hybrid coil, and the carrier wave from the oscillator 78 is interrupted in accordance with such signaling current input to relay F. The modulated carrier wave is transmitted to the power line and over the latter to all the stations connected to it. The modulated wave is transmitted by the filter 50 and amplifier 35, and the demodulated wave is delivered to the station signal 37. The particular subscriber whose code has been signaled answers by removing his receiver and transmitting on carrier wave F2 and receiving on carrier wave F1.

It was assumed in the situation described in the paragraph immediately above that the power line was not in use, i. e., that two of the telephone stations coupled to it were not carrying on a conversation. That the power line was "busy" would be indicated, however, in the following manner. It has already been pointed out that, on a reverting call or call local to the power line system, the calling party transmits on the carrier wave F1 and receives on the carrier wave F2, and that the called party transmits on the carrier wave F2 and receives on the carrier wave F1. Since each telephone station A is arranged in its normal condition to receive on the carrier wave F1, and signaling from one station A to another on the power line is on the carrier wave F1, signaling between the stations has no effect on the central office inasmuch as the receiving circuit 11' contains the band-pass filter 60' that transmits only the carrier wave F2 and one or more of its side-bands. When the called party answers, however, the called party's oscillator supplies the carrier wave F2 to the line, and transmitting out of the called station is by modulating the carrier wave F2. As soon as the carrier wave F2 appears on the power line, relay H is operated; i. e., the carrier wave is transmitted by filter 60' to the amplifier 72 and demodulator 73 and energizes relay H. The normally open contact sets of the relay H close and its contact set 2 connects the sleeve conductor S to ground causing the line terminal to test busy at the connector terminal in equipment 200 until the called party disconnects.

Description of modified central office, Fig. 3

It will be observed from the above description of circuit operation that every reverting call involves an unguarded interval: revertive ringing or signaling by the calling subscriber does not cause the line connected to the power line through the carrier frequency equipment and relay arrangement at the central office to test busy at the connector terminal. The calling party signals on carrier wave F1, whereas, the central office receives the carrier wave F2 only. The line is not guarded or rendered "busy" until the called subscriber answers and places carrier wave F2 on the power line. Fig. 3 shows a circuit arrangement that is a modification of the central office of Fig. 1, and that overcomes this condition. The central office CO' is the same as that of the central office CO of Fig. 1 except that relay G includes a lower contact set, and a filter 90 pass-

ing carrier wave F1 is connected to the receiving circuit 11'. An amplifier 91 and demodulator or detector 92, provided with an A. V. C. connection 93, are connected to the output of the filter, a relay K being connected in the output circuit of the demodulator. As soon as carrier wave F1 is applied to the power line by a calling subscriber thereon, relay K is energized, its normally open contact is set closed and the sleeve lead S is connected to ground at the lower contact set of relay G, thus protecting the power line from intrusion by a call incoming to the central office from other than the power line telephone system. When there is transmission on carrier wave F1 out of the central office to the power line, relay K might be energized, but the outgoing transmission is not affected.

Description of power line telephone system of Fig. 2

The arrangement described with reference to Figs. 1 and 3 requires three conductors (tip, ring, sleeve) between the dial equipment 200 and the carrier terminal or "convertor" equipment at the central office CO or CO'. In the system of Fig. 2 only two conductors (tip and ring) are required between the carrier terminal equipment and the circuit 200. With the arrangement of Fig. 2, the carrier frequency equipment interconnecting the high frequency and the low frequency portions of the system can be located at any convenient point along the power line, and be connected with the machine switching equipment 200 at a point remote from the power line over an ordinary two-conductor metallic line.

The telephone station A' of Fig. 2 is the same as station A of Fig. 1 except that the key or button 43 is omitted, and the key 32' serves the dual function of completing an energizing circuit for relay 20, and of completing the energizing circuit for the interrupter 28. The central office CO2 is similar to the central office CO of Fig. 1 in that it includes a carrier frequency transmitting circuit 10', a carrier frequency receiving circuit 11', a hybrid coil 70' for interconnecting the audio-frequency circuit of the central office with the carrier frequency circuits connected to the power line, a circuit 95 for causing the power line to test "busy" at the central office during the period a reverting call is being completed, and a plurality of relays K1, H1 and D1 for supervising a connection between a station on the power line and the central office and for establishing appropriate signaling and supervisory conditions at the central office during either a reverting call or one completed through the central office. The number of relays required at the central office in the system of Fig. 2 is less than in that of Fig. 1. The contact sets associated with the relays are shown in their condition of rest, i. e., when the power line telephone system is not in use. The operation of the system of Fig. 2 with respect to a call local to power line stations, and a call completed through the central office to or from one of the power line telephone stations will now be described.

Call between power line telephone stations, Fig. 2

The making of a call local to the power line is substantially the same as with the system of Fig. 1. The calling party removes his receiver from the hook 41, and carrier wave F2 is supplied to the power line. Closure of key 32' completes an energizing circuit for the upper winding of relay 20, which locks up through its lower winding and associated contact set connected to ground through the switchhook 41. The oscillator output is shifted to carrier wave F1, and, with the interchange of filters 50, 60 between the transmitting and receiving circuits 10, 11, carrier wave F1 is transmitted to the power line through filter 50 and the station is adapted to receive on carrier wave F2. Operation of key 32' in accordance with the signaling code for the power line telephone system modulates the carrier wave F1 in accordance therewith. The modulated carrier wave is transmitted to all of the other telephone stations on the line and, since each station is adapted normally to receive on carrier wave F1, the station signal 37 at each station is operated by the demodulated output of its demodulator 36. The called station answers by the removal of its receiver from its hook, and the beginning of the conversation by transmission on carrier wave F2 since the relay 20 of the called station is not energized. When the call is terminated, the called and calling parties replace their receivers on the switchhooks at the stations.

When the calling party initiates the call by removing his receiver from its hook, there is a short interval before he operates the key 32' during which carrier wave F2 is supplied to the power line. This carrier wave incoming to the central office is transmitted by the filter 60' to the amplifier and demodulator of the receiving circuit 11'. The relay H1, connected in the demodulation circuit, is energized, and closure of its contact set 1 closes the loop between conductors T, R through the hybrid coil, and causes the line to test busy at its connector terminal; the carrier frequency circuit is thus protected from intrusion from the central office. After the calling station starts signaling by operation of key 32' and, thus, is transmitting on the carrier wave F1, relay H1 releases, but relay K1 operates. The modulated carrier wave F1 is not only transmitted to the other stations on the power line, but is received at the central office through the circuit 95. Filter 90' transmits the modulated wave to amplifier 91' and demodulator 92' in whose output circuit the relay K1 is connected. Energization of relay K1 opens its normally closed contact set 1 disconnecting ground from relay H1, and closes its normally open contact set 2, thus placing a short circuit on the conductors T, R and causing the line to test busy at the connector terminal. While relay K1 is operated and relay H1 is released, the normally open contact set 3 of relay H1 remains open; the oscillator 78' remains unoperated. It is assumed that the line circuit of the equipment 200 is of the lock-out type, such as is commonly employed in community dial offices; if it is not, a link or line finder and first selector will be held up during the reverting call.

As already described, the audio frequency line loop at the central office is closed initially by the operation of relay H1 and, when the calling station shifts from carrier wave F2 to F1, this closure is replaced by the operation of relay K1. Relay H1, however, must be able to function as a pulse repeating relay on calls from a station A' to the central office CO2; this requires that it be of the fast-release type. Relay K1, therefore, should be of a very fast-operating type so that any pulse generated between the release of relay H1 and the energizing of relay K1 will be of insufficient duration to cause false operation of the dial equipment at the telephone exchange.

Call between power line telephone station and central office, Fig. 2

To make a call through the central office, the subscriber at a station A' removes his receiver from its hook. The carrier wave F2 transmitted to the line and received at the central office causes relay H1 to operate as already described. Closure of contact set 1 of relay H1 completes the line loop for conductors T, R through the hybrid coil; and closure of contact set 3 and opening of contact set 2 of relay H1, respectively, connects source 98 to the oscillator 78' to energize the latter, and removes ground from relay K1. Dial tone from equipment 200, supplied over the conductors T, R and through the lower winding of the hybrid coil, is modulated on the carrier wave F1 in modulator 75' and transmitted through filter 50' and amplifier 76' to the power line and over the latter to the calling station. At the latter, the dial tone modulated carrier wave is demodulated and dial tone appears in the receiver. The calling party does not operate his key 32', hence the station transmits on carrier wave F2 and receives on carrier wave F1. The calling party operates his dial 45 in the conventional manner and the break-and-make of impulse springs 46 modulate the carrier wave F2 in accordance therewith. The pulse modulated wave is received at the central office CO2 and the relay H1 repeats the dial pulses into the central office dial equipment. When the connection to the called party is complete, conversation between the calling station A' and the calling party proceeds as in the case of the system of Fig. 1.

When a call is incoming to a station of the power line telephone system from the central office, the operation of the system of Fig. 2 is as follows. When the line comprising conductors T, R is seized, relay D1 follows the ringing current supplied by the connector. This relay is tuned to a low frequency, e. g., 20 C. P. S., and closes its contact set 1 and opens its contact set 2 at that rate whereby the oscillator 78' has energizing potential connected to it twenty times a second during each ringing period; accordingly, carrier wave F1 is applied to the power line at that rate and transmitted to all stations A'. When the station A' whose code has been used answers, carrier wave F2 originating at the station causes relay H1 at the central office to operate, closing the loop for conductors T, R through the hybrid coil over contact set 1 of relay H1, and energizing the oscillator 78' over contact set 3 of relay H1. When the call is terminated and the parties restore their receivers to their supports, the circuit of the central office CO2 restores to the condition shown on the drawing.

Although this invention has been disclosed with reference to certain specific embodiments, it will be understood that it is not limited thereto, but is of a scope evidenced by the appended claims.

What is claimed is:

1. In a power line carrier frequency telephone system comprising a power line, a plurality of carrier frequency telephone stations coupled to said line and adapted to establish direct connection with one another over said line, and a central office including means adapted to be actuated by carrier frequency pulses originating at a power line telephone station for connecting the latter with a telephone station of another telephone system, and, in which, after a connection is established between two of the telephone stations coupled to the power line, one of said stations transmits and receives on a first and a second carrier wave, respectively, and the other of said stations transmits and receives on said second and first carrier waves, respectively; means at said central office, responsive to each of said carrier waves at different stages of establishment of the connection between the power line telephone stations to prevent a call incoming to the power line from the central office interfering with the connection being established on the power line.

2. A power line telephone system comprising a power line, a high frequency telephone station connected to said line, means at said station for generating a plurality of high frequency electric waves, a circuit for connecting the power line to an automatic telephone exchange through which a telephone station coupled to the power line may be connected to a telephone station not coupled to the power line, said connecting circuit including an audio frequency line for connecting it with the automatic exchange, means at said power line station for transmitting a pulse of one of said high frequency waves over said power line to said connecting circuit, means in said connecting circuit responsive to said pulse to cause said audio frequency line to test busy at said automatic exchange during said pulse, means in said power line station to prevent further transmission of said one high frequency wave and to transmit pulses on said second high frequency wave over said power line to said connecting circuit, and means in said connecting circuit responsive to the pulses of said second high frequency wave to transmit corresponding pulses over said audio frequency line to the automatic exchange.

3. A power line telephone system comprising a power line, a plurality of telephone stations coupled to said power line, a circuit for connecting the power line with an automatic telephone exchange whereby said telephone station may be connected through said automatic exchange with telephone stations that are not coupled to the power line, said connecting circuit including an audio frequency line for connecting it with the automatic exchange, each telephone station connected to the power line including means to generate two different high frequency electric waves, means at each of said power line stations for signaling to another power line station on one of said high frequency waves, means in said connecting circuit responsive to said one high frequency wave to cause the audio frequency line to test busy at the exchange during said signaling, means at each power line station for responding to a calling signal from another of said power line stations by transmitting to the calling station on the second of said high frequency waves, and means in said connecting circuit responsive to said second high frequency wave to cause the audio frequency line to test busy at the automatic exchange during the remainder of a connection between the power line telephone stations.

4. A power line telephone system comprising a power line, a plurality of high frequency telephone stations connected to said line, means at each of said stations for generating a plurality of high frequency waves, a circuit for connecting the power line to an automatic telephone exchange, said circuit including an audio frequency line, means at each power line station for transmitting and receiving on each of said high fre-

quency waves, each station normally being in condition to receive on the same one of said high frequency waves and being adapted to transmit initially on a second of said high frequency waves, switching means at each station to enable it to transmit on said one wave and to receive on said second wave, said switching means being operated when it is desired to establish a connection with a second station on the power line, means in said connecting circuit responsive to said second wave transmitted to the power line from one of said stations in initiating a connection with a second of said stations, prior to operation of the switching means at said one station, for causing said audio frequency line to test busy at the exchange, and additional means in said connecting circuit responsive to said first wave after said switching means has been operated, to maintain the busy condition of said audio frequency line until said second station responds to signaling from said one station on said first wave and transmits on said second wave.

5. A telephone system comprising a transmission line, a plurality of carrier frequency telephone stations coupled to said line, said stations being adapted to signal and to communicate directly with each other over said line on two carrier frequency waves, and a circuit for connecting said transmission line with an automatic telephone exchange, said circuit including an audio frequency line connecting it with the exchange, a carrier frequency line connecting the circuit with said transmission line and a carrier frequency receiving circuit, said receiving circuit including a plurality of networks selective to a plurality of preassigned frequency bands, one band including one of said carrier waves and another including the second of said carrier waves, a demodulator connected to the output of each network, and a plurality of relays each responsive to the output of a different one of said demodulators for rendering said audio frequency line busy to a call incoming to the telephone system from the exchange when either carrier wave is applied to the transmission line during the period of a connection between stations on the transmission line.

6. A telephone system comprising a transmission line, a plurality of telephone stations coupled to said line, a circuit for connecting the line with a telephone exchange whereby said telephone station may be connected through said exchange with a telephone station not coupled to the transmission line, said connecting circuit including an audio frequency line for connecting it with the exchange, each transmission line station including means to generate two different high frequency electric waves, means at each of said transmission line stations for signaling to another transmission line station on one of said high frequency waves, means in said connecting circuit responsive to said one high frequency wave to cause the audio frequency line to test busy at the exchange during such signaling, means at each transmission line station for responding to a calling signal from another of said transmission line stations by transmitting to the calling station on the second of said high frequency waves, and means in said connecting circuit responsive to said second high frequency wave to cause the audio frequency line to test busy at the exchange during the remainder of a connection between the transmission line stations.

7. A telephone system comprising a transmission line, a plurality of carrier frequency telephone stations coupled to said line, said stations being arranged to establish and maintain a connection directly with each other over said line, each station, when the calling station, signaling to the called station on a first carrier wave, transmitting on the same carrier wave and receiving on a second carrier wave, and each station, when the called station, transmitting to the calling station on said second carrier wave and receiving from the calling station on said first carrier wave, a circuit connected to said line to enable each of said stations to communicate with a telephone station not coupled to said line, said circuit including an audio frequency line leading to an exchange for said last-mentioned station, each transmission line circuit when communicating through the connecting circuit signaling and transmitting on said second carrier wave and receiving on said first carrier wave, said connecting circuit including a receiving circuit to receive on said second carrier wave and a transmitting circuit to transmit on said first carrier wave, means in said connecting circuit responsive to said first carrier wave when a transmission line station is signaling to a second transmission line station to cause said audio frequency line to test busy at the exchange, and means in said receiving circuit responsive to said second carrier wave when a transmission line station is connected through the connecting circuit with the exchange, to disable said last-mentioned means against operation by said first carrier wave as transmission from said connecting circuit to said transmission line takes place on said first carrier wave.

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