April 27, 1948. M. L. ALMQUIST 2,440,239

TWO WAY CARRIER WAVE TELEPHONE SYSTEM

Filed Dec. 6, 1945 3 Sheets-Sheet 1

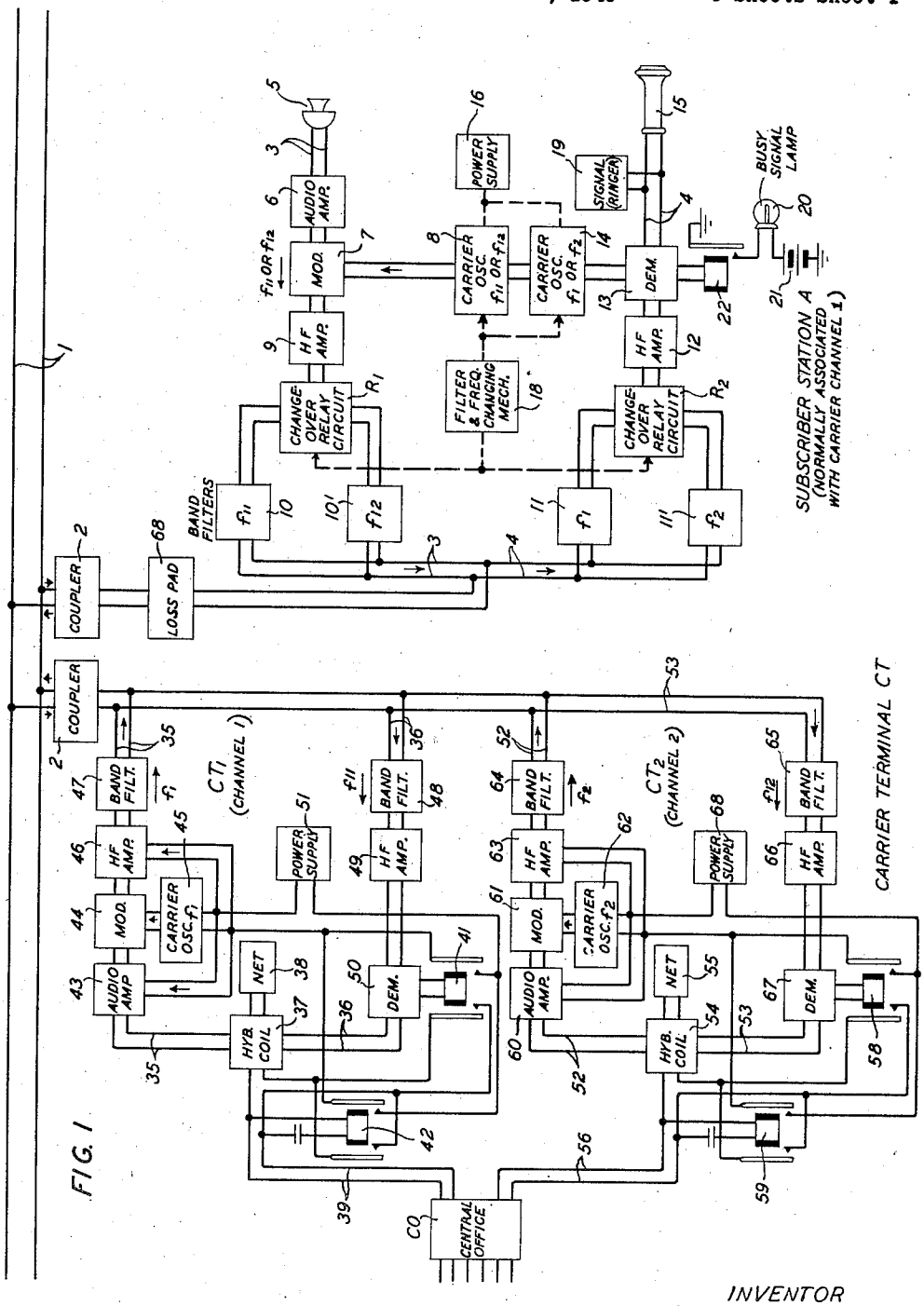

FIG. 1

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Filed Dec. 6, 1945 3 Sheets-Sheet 2

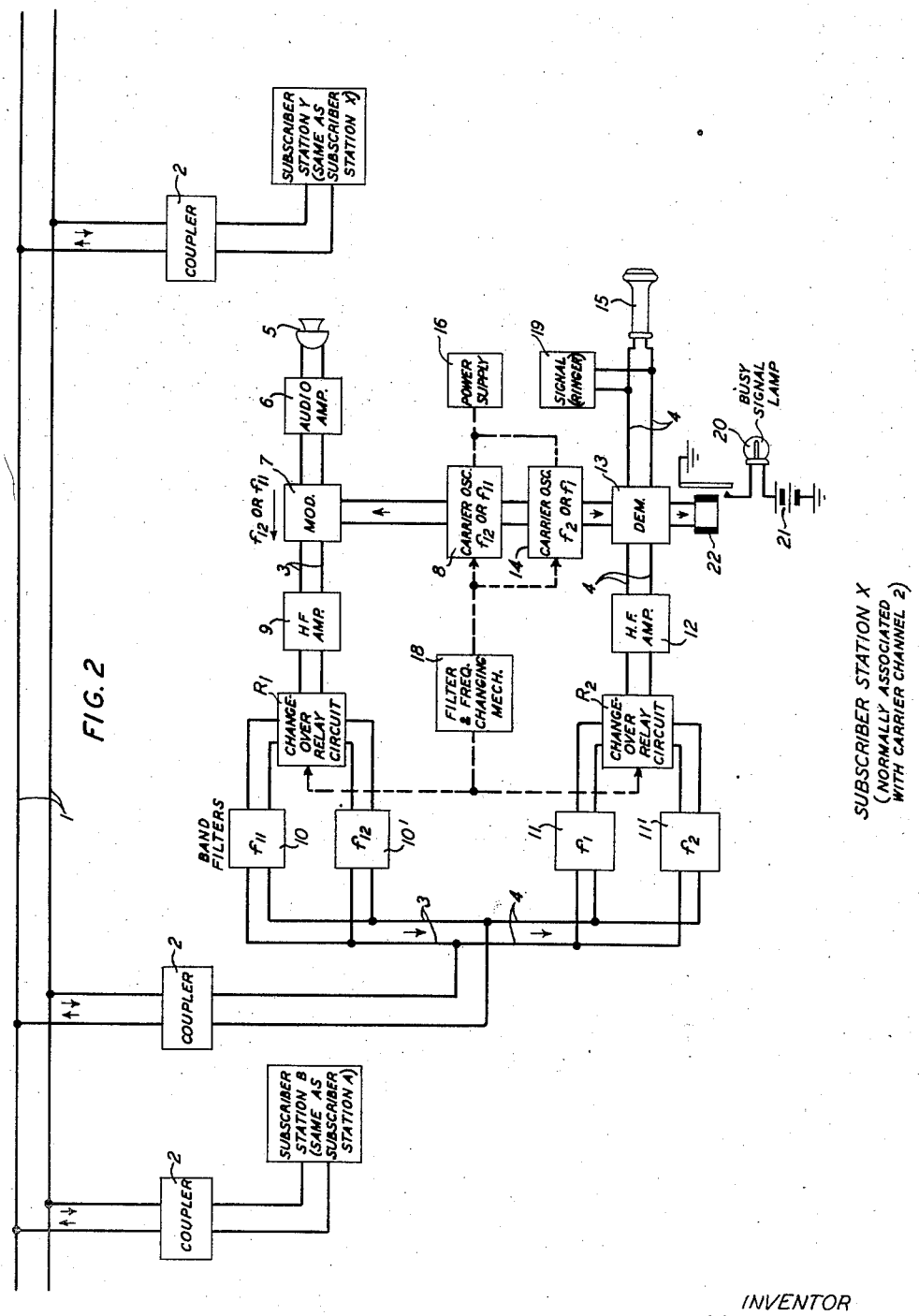

FIG. 2

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FIG. 3

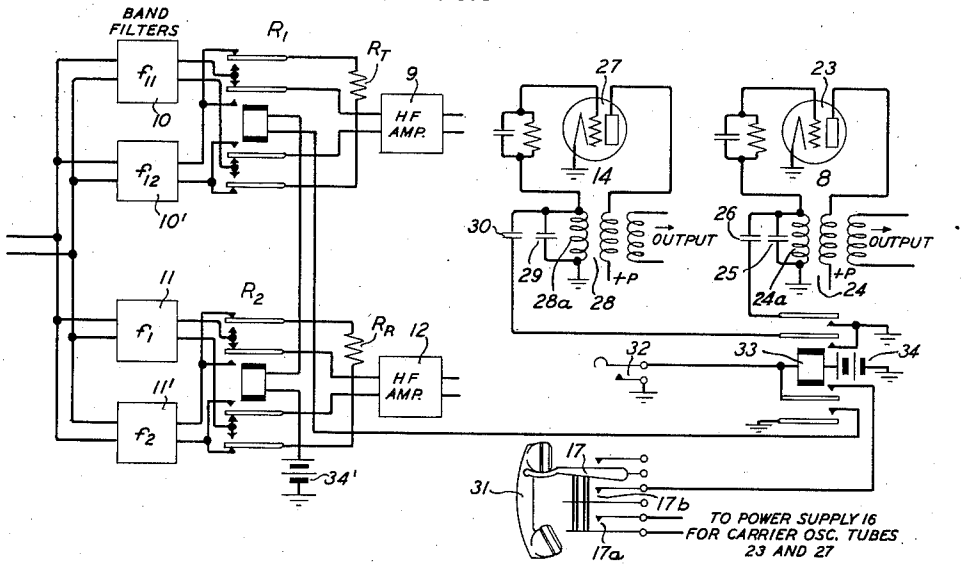
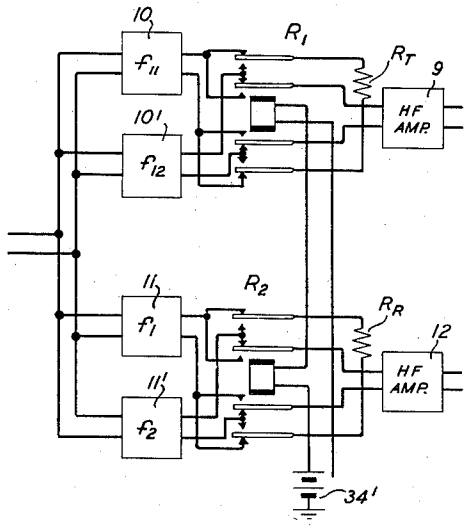


FIG. 3A



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Patented Apr. 27, 1948

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UNITED STATES PATENT OFFICE

2,440,239

TWO-WAY CARRIER WAVE TELEPHONE SYSTEM

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Application December 6, 1945, Serial No. 633,205

9 Claims. (Cl. 179—15)

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This invention relates to an electric wave transmission system and particularly to an electric communication system employing high frequency carrier waves for transmitting the communication signals.

The invention is specifically applicable to a communication system employing a number of high frequency carrier channels to provide two-way telephone service to telephone subscribers over a common transmission medium. In such a system, the common medium may be a transmission line, for example, one used primarily for supplying low frequency, high voltage power to a number of power consumers in a power distribution network, or one or more radio transmission links. Each carrier channel may be utilized for providing two-way communication between each two telephone subscribers on a party line basis over the line or other common transmission medium through an individual carrier terminal having an associated central switching office common to the several channels. The central office associated with the carrier terminals may provide means for connecting the carrier telephone subscriber stations associated with each carrier channel on the common medium in communication relation with each other or with other telephone subscriber stations on other carrier channels on the same medium or on outside systems.

In such prior art systems, it is known to utilize two different carrier frequencies for each carrier channel for transmission between the carrier terminal equipment and the subscriber's equipment, one for each direction of transmission. The subscriber's equipment is normally arranged to transmit on one carrier frequency f_2 and to receive on a second carrier frequency f_1 and the carrier terminal equipment is arranged to transmit on carrier frequency f_1 and receive on carrier frequency f_2 or f_1. To make a reverting or party line call, that is a call between subscribers on the same carrier channel, the transmitting and receiving frequencies of either the calling or called station are reversed. In this case it is necessary to prevent transmission of the carrier frequency f_1 from the carrier terminal during the call since the presence of this frequency would cause beats with the subscriber's transmitter using this same frequency and thus produce distortion in the transmitted communication signals. In addition, it is necessary to provide a busy indication at the central office.

An object of the invention is to improve this general type of system from the standpoint of

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circuit simplicity, economy of equipment, reduction in frequency selectivity requirements and operating procedures.

Another object is to provide two-way communication between any two of a number of subscribers associated with each carrier channel of a multichannel carrier communication system on a party line basis, as well as to provide two-way communication between any subscriber on each carrier channel of such a system and another subscriber on another carrier channel of the same system or on any other system or line to which this carrier system may be connected.

In accordance with the invention, a multichannel carrier communication system of the general type described above is modified so that all communication connections, both between the subscribers associated with each carrier channel on the line or other common transmission medium and other subscribers outside that channel or carrier system, and between subscribers on the same carrier channel of the carrier system, are made through the central office in the same manner. This is accomplished by giving each subscriber on each carrier channel access to a second carrier channel on the common transmission medium to which he can connect by operation of a key provided on his subscriber's communication set. Each subscriber of a group assigned to one carrier channel on the common transmission medium normally utilizes one carrier frequency for receiving from the carrier terminal for that channel and a second carrier frequency for transmitting to that carrier terminal. Provision is made in the subscriber's communication set whereby the transmitting and receiving carrier frequencies of the set can be shifted to other different frequencies which are respectively the normal transmitting and receiving carrier frequencies utilized by the subscriber sets associated with another carrier channel on the common transmission medium.

In making a call to a subscriber outside the carrier system or to a subscriber on another carrier channel of the same system, the subscriber associated with one carrier channel on the common transmission medium merely has to lift his receiver or telephone handset off the switchhook, in which case his set is conditioned for transmitting on one carrier frequency and receiving on a second carrier frequency. The first carrier frequency is transmitted over a common medium to the carrier terminal for that channel where it is utilized to call in the central office operator, for example, by closing a normally open trans-

mission loop to the central office to operate a suitable alarm device, and to cause the energization of the normally disabled transmitter at the carrier terminal so that it sends out the second carrier frequency over the common transmission medium to operate a busy signal at each of the subscriber stations on the same carrier channel.

To make a party line call, the calling subscriber on any channel normally transmitting on one carrier frequency and receiving on a second carrier frequency, when the unoperated condition of his busy signal indicates that the channel is idle, presses a non-locking key which causes his set to be conditioned for transmitting on a third carrier frequency and receiving on a fourth carrier frequency normally assigned to a second carrier channel on the same common transmission medium. If this second carrier channel is idle, no busy signal will be received at the calling station. The subscriber then lifts his receiver or handset off the hook, thereby locking his set on the alternate frequency assignment and sending the third carrier frequency out over the common line or other medium to operate a busy signal at each subscriber's station on the alternate carrier channel. The received third carrier frequency at the carrier terminal for the alternate channel will control switching arrangements operating to call in the operator at the central office, and to energize a transmitter at that carrier terminal to send out the fourth carrier frequency over the common medium. The central office operator then completes the call to the called subscriber on the subscriber's normal channel through the central office switchboard in the usual manner, and the two subscribers converse with each other through the central office. When the call is completed, the calling subscriber hangs up his receiver and his set automatically reverts to the frequencies of the carrier channel to which he is normally assigned.

A more complete understanding of the invention will be obtained from the following detailed description when read in connection with the accompanying drawings in which:

Figs. 1 and 2, when placed side by side with Fig. 1 at the left, show in block schematic form a power line carrier telephone system embodying the invention; and

Fig. 3 shows schematically one type of variable frequency carrier oscillator and band filter switching arrangement and the control circuits therefor, which may be used at each of the subsubscribers' stations associated with one carrier channel in the system of Figs. 1 and 2; and

Fig. 3A shows schematically a modification of a portion of the arrangement of Fig. 3 to make the arrangement suitable for use at each subscriber station associated with a second carrier channel in the system of Figs. 1 and 2.

The power line carrier telephone system of Figs. 1 and 2 includes a transmission line 1 primarily employed for transmission and distribution of low frequency, high voltage, electric power and adapted for simultaneous use for high frequency carrier wave telephony. The line 1 is shown as a single phase line having one wire grounded but the carrier telephone system to be described may be applied to any type of power or other transmission line. A plurality of two-way carrier telephone channels having different frequency assignments are applied to a given section of the power line 1, of which only two channels, designated channels 1 and 2, have been illustrated in order to explain the invention. Each channel may form a party line with six to eight, or possibly more, subscribers. As shown, channel 1 comprises a plurality of subscriber two-way carrier telephone stations designated A, B . . . and an individual portion CT_1 of a two-way carrier terminal CT, and channel 2 a plurality of subscribers' two-way carrier telephone stations X, Y . . . and other individual portion CT_2 of the two-way carrier terminal CT. Each of the subscribers' stations A, B . . . and X, Y . . . and the carrier terminal CT are bridged across the power line 1 by suitable coupler arrangements 2, which may comprise condensers or filter arrangements (not shown), adapted for permitting the transmission of the high frequency carrier signals to or from the line and for substantially preventing transmission of the low frequency, high voltage power from the line into the subscriber's carrier telephone and the carrier terminal equipment.

Each of the portions CT_1 and CT_2 of the carrier terminal CT are adapted for connection to the common central switching office, CO, through individual line loop connections to be described later.

The subscribers' stations A, B . . . in channel 1 and the subscribers' stations X, Y . . . in channel 2 are identical except for the changes in the carrier oscillators and band filters and the frequency changing control mechanisms therefor required because of the different transmitting and receiving frequencies assigned to the two channels for the normal and switched operating conditions, to be described.

Each of the subscribers stations A, B, . . . and X, Y . . . , as shown, comprises a transmitting circuit 3 and a receiving circuit 4. The transmitting circuit 3 includes in order, reading from right to left, a telephone transmitter 5 (which may be part of a standard hand telephone set as illustrated in Fig. 3), an audio amplifier 6, a modulator 7 with its associated carrier oscillator 8, a high frequency transmitting amplifier 9 and the transmitting band filters 10 and 10' with an associated change-over relay circuit R_1, feeding into the line 1 through the coupler device 2. The receiving circuit 4 includes in order, reading from left to right, the receiving band filters 11 and 11' with an associated change-over relay circuit R_2, fed from the line 1 through the coupler device 2, the high frequency receiving amplifier 12, the demodulator 13 with an associated carrier oscillator 14, and the telephone receiver 15 (which may be combined in a standard hand telephone set with the telephone transmitter 5, as shown in Fig. 3.)

The modulator 7 and the demodulator 13 may be of any of the well-known types including one or more electron discharge tubes or other variable resistance devices, respectively adapted to combine high frequency carrier oscillations supplied to its carrier input terminals with the audio frequency signals supplied to its signal input terminals so as to produce signal side-band components as well as the unmodulated carrier component in its output, and to combine high frequency carrier oscillations supplied to its carrier input terminals with the unmodulated or modulated carrier signals supplied to its signal input terminals to produce the rectified carrier or the modulating audio signals in its output.

The carrier oscillator 8 associated with the modulator 7 and the carrier oscillator 14 associated with the demodulator 13, when energized by the common power supply 16 by the closing of a switch, which may be the switch contacts 17a

of the telephone hook switch 17, such as shown in Fig. 3, are adapted to supply to the associated modulator 7 and demodulator 13, respectively, carrier oscillations either of the high frequency f_{11} or f_{12} and f_1 or f_2, respectively, depending on the operated condition of the associated key-controlled oscillator frequency changing and filter switching mechanism 18, one type of which will be described later in connection with Figs. 3 and 3A.

Also included in the receiving circuit 4 at each subscriber's station is a station signaling device 19 associated with the output of the demodulator 13, which may be a voice frequency ringer responsive to the frequency at which the received carrier is modulated, such as 20 cycles per second, during ringing intervals; and a busy signal lamp 20 adapted to be operatively energized from the battery 21 by the operation of the electromagnetic relay 22 by the rectified output current of the demodulator 13 when high frequency carrier signals are applied to the input of the latter.

The band filters 10 and 10' in the transmitting circuit 3 are adapted to selectively transmit voice signal-modulated carrier waves (one or both signal side-bands) of the high frequency carriers f_{11} and f_{12}, respectively, supplied thereto from the output of the modulator 7, as well as the unmodulated carrier components of these frequencies, and the band filters 11 and 11' in the receiving circuit 4 are adapted to selectively transmit the voice signal-modulated carrier waves of the high frequencies f_1 and f_2, respectively, as well as the unmodulated carrier components of those frequencies, received from the line 1.

As illustrated in Fig. 3, the carrier oscillator 8 associated with the modulator 7 at each subscriber's station may comprise a single three-electrode electron discharge tube 23 having its plate circuit coupled to its grid circuit through the feedback winding 24a of output transformer 24, the effective inductance of that transformer winding and the capacitances of the associated condensers 25 and 26 of suitably selected values determining the frequency of oscillation. Similarly, the carrier oscillator 14 associated with the demodulator 13 at each subscriber's station may comprise a single three-electrode electron discharge tube 27 having its plate circuit coupled to its grid circuit through the feedback winding 28a of output transformer 28, the effective inductance of that transformer winding and the capacitances of the associated condensers 29 and 30 determining the frequency of oscillation of the latter oscillator. The two oscillator tubes 23 and 27 are normally deenergized and are adapted to be energized from the associated power supply 16 when the subscriber removes his handset 31 from the telephone hook switch 17 by the resultant closing of its normally open lower switch contacts 17a in the energizing circuit for the two oscillator tubes. In the normal condition of the oscillator circuits shown, with the condenser 25 only connected in shunt with the feedback winding 24a and the condenser 29 only connected in shunt with the feedback winding 28a, the frequency determining circuits of the oscillators 8 and 14, respectively are tuned so that these oscillators, when energized, will oscillate at different high frequencies determined by the values of the respective shunting condensers. With the oscillator tubes 23 and 27 energized (handset 31 off the switchhook 17), the tuning of these oscillators may be changed so that they oscillate at two other respectively different high frequencies by the closing of the non-locking key 32. This closes an operating circuit for the electromagnetic relay 33 from battery 34. With relay 33 operated, the additional condenser 26 of suitably selected value is connected in shunt with the feedback winding 24a of transformer 24 and the additional condenser 30 of suitably selected value is connected in shunt with the feedback winding 28a of output transformer 28, which changes the tuning of the two oscillators to the required different frequencies; and the relay 33 is locked operated from battery 34 through the closed upper set of the lower switch contacts of that relay and the closed upper switch contacts 17b of hook switch 17 in series, so as to maintain the two oscillators tuned to the changed frequencies when the frequency change key 32 is released. When the handset 31 is replaced on the hook switch 17, the upper and lower sets of switching contacts 17b and 17a, respectively, of that switch are returned to the open condition, as shown, disconnecting the power supply 16 from the oscillator tubes 23 and 27 and releasing relay 33 so as to revert the tuning of the two oscillators 8 and 14 to their normal frequencies.

At each of subscriber stations A, B . . . associated with carrier channel 1 in the system of Figs. 1 and 2, the values of the tuning condensers 25 and 26 in the modulator carrier oscillator 8 and the tuning condensers 29 and 30 in the demodulator carrier oscillator 14, are selected so that these two oscillators, when energized, normally oscillate at the high frequencies f_{11} and f_1 respectively. The respective oscillating frequencies of oscillators 8 and 14 are changed to the high frequencies f_{12} and f_2, respectively, by the operation of the key 32 in the manner which has been described.

However, at each of the subscribers' stations X, Y . . . associated with carrier channel 2 in the system of Figs. 1 and 2, the values of the tuning condensers 25 and 26 associated with the modulator carrier oscillator 8 and of the tuning condensers 29 and 30 associated with the demodulator carrier oscillator 14 are selected so that the former when energized normally oscillates at the high frequency f_{12} and the latter, when energized, at the high frequency f_2, and their tuning frequencies are respectively changed to the frequencies f_{11} and f_1 when the key-controlled mechanism 18 is operated.

As illustrated in Fig. 3, at each of the subscriber's stations A, B . . . associated with channel 1 on the line 1, the change-over relay circuits R_1 and R_2 respectively associated with the band filters 10 and 10' in transmitting circuit 3 and with the band filters 11 and 11' in the receiving circuit 4, are arranged so that with relay 33 unoperated, band filters 10 and 11 adapted to selectively transmit the unmodulated and modulated carriers of the frequencies f_{11} and f_1, respectively, are connected to the output of the high frequency amplifier 9 in transmitting circuit 3 and the input of the high frequency amplifier 12 in receiving circuit 4, respectively, and the other filters 10' and 11', adapted to selectively transmit the unmodulated and speech-modulated carriers of the frequencies f_{12} and f_2, respectively, are effectively disconnected from these circuits and terminated by the resistors R_T and R_R, respectively. When relay 33 at the station is operated in response to operation of the key 32 by the local subscriber, the change-over relay circuits R_1 and R_2 are operatively energized in series from battery 34' through the made

lower contacts of relay 33 so as to respectively connect the based filters 10' and 11' to the output of the high frequency amplifier 9 in the transmitting circuit 3 and the input of the high frequency amplifier 12 in the receiving circuit 4, to effectively disconnect the band filters 10 and 11 from these respective circuits and to switch the resistance terminations from filters 10' and 11' to the filters 10 and 11, respectively.

As illustrated in Fig. 3A, at each of the subscriber's stations X, Y . . . associated with channel 2 in the system of Figs. 1 and 2, when the relay 33 is in the unoperated condition, the switching contacts of the change-over relay circuits R_1 and R_2 at each station may be arranged so that the band filters 10' and 11', adapted to respectively selectively transmit the unmodulated frequencies f_{12} and f_2, which are the normal transmitting and receiving carrier frequencies assigned to stations associated with carrier channel 2, are connected to the output of the high frequency amplifier 9 in the transmitting circuit 3 and to the input of the high frequency amplifier 12 in the receiving circuit 4, and the band filters 10 and 11, respectively, adapted to selectively transmit the unmodulated and modulated carriers of the frequencies f_{11} and f_1, which are the normal transmitting and receiving carrier frequencies of the subscriber's stations associated with carrier channel 1, are effectively disconnected from these circuits and terminated with the resistors R_T and R_R, respectively. When relay 33 at the station is operated in response to operation of the key 32 by the local subscriber, the change-over relay circuits R_1 and R_2 so modified are operatively energized in series from the battery 34' through the lower made contacts of relay 33 so as to respectively connect the band filters 10 and 11 to the output of the high frequency amplifier 9 in transmitting circuit 3 and the input of the high frequency amplifier 12 in receiving circuit 4, to effectively disconnect the band filters 10' and 11' from these respective circuits and switch the resistance terminations R_T and R_R from band filters 10 and 11 to band filters 10' and 11', respectively.

The portion CT_1 of the carrier terminal CT, associated with carrier channel 1 on power line 1 in the system of Figs. 1 and 2, comprises a transmitting circuit 35 and a receiving circuit 36. The output of the transmitting circuit 35 and the input of the receiving circuit 36 are connected in parallel with each other and through the coupler device 2 to the line 1. The input of the transmitting circuit 35 and the output of the receiving circuit 36 are connected by means of the hybrid coil 37 and associated line balancing network 38 to the two-wire voice frequency line 39 leading to the common central telephone switching office CO for the subscribers' stations associated with both carrier channels 1 and 2 on the power line 1. The central office CO, which may be either of the manual or automatic type, is utilized also for connecting the telephone subscribers associated with each carrier channel of power line 1 to any of the telephone subscribers' stations outside the carrier system in the associated telephone network. The central office CO is normally disconnected from the carrier terminal portion CT_1 due to the normal break in the line 39 provided through the normally open, parallel-connected left-hand switching contacts of the relays 41 and 42 to be referred to later. The operation of either one of these two relays to close its left-hand switching contacts will complete the connection of the line 39 to the central office CO.

The transmitting circuit 35 of carrier terminal portion CT_1 includes in order, between the hybrid coil 37 and the coupler device 2, reading from left to right, an audio amplifier 43, a modulator 44, similar to the modulator 7 in each carrier subscriber's station, with an associated carrier oscillator 45 for supplying thereto carrier oscillations of the high frequency f_1, the high frequency transmitting amplifier 46 and the transmitting directional band filter 47, adapted to transmit one or both signal side-band products as well as the unmodulated carrier component of the frequency f_1 received from the output of the modulator 44. The receiving circuit 36 includes in order, between the coupling device and the hybrid coil 37, reading from right to left, the directional band filter 48 adapted for selectively transmitting the speech-modulated and unmodulated carrier waves of the frequency f_{11} received from the line 1, the high frequency amplifier 49 and the demodulator 50 for demodulating the applied high frequency carrier signals of the frequency f_{11} to voice frequencies, and for rectifying the applied unmodulated carrier of that frequency.

The audio amplifier 43, the high frequency transmiitting amplifier 46, and the carrier oscillator 45 associated with the transmitting circuit 35 in the carrier terminal portion CT_1 are normally deenergized. They are adapted to be energized from the power supply 51 through the made right-hand, parallel-connected switching contacts of either of the two switching relays 41 and 42 when that relay is operated. The relay 41 operates in response to the rectified output current of the demodulator 50 in the receiving circuit 36 when a received carrier wave of the frequency f_{11} is applied to the input of the latter demodulator; and relay 42 operates in response to ringing current, say, of the frequency 20 cycles per second, transmitted from the central office CO over the voice frequency line 39.

Similarly, the portion CT_2 of the carrier terminal CT, associated with carrier channel 2 on the power line 1, comprises a transmitting circuit 52 and a receiving circuit 53. The output of the transmitting circuit 52 and the input of the receiving circuit 53 are connected in parallel with each other and through the common coupler device 2 to the line 1. The input of the transmitting circuit 52 and the output of the receiving circuit 53 are connected by means of the hybrid coil 54 and associated line balancing network 55 to the two-wire voice frequency line 56 leading to the common central telephone switching office CO for the subscriber stations associated with both channels 1 and 2 on power line 1, and utilized also for connecting the telephone subscribers on carrier channel 2 of power line 1 to any of a number of telephone subscribers' stations outside the carrier system in the associated telephone network. The line 56 leading to the central office CO is normally held open through the normally open parallel-connected, left-hand switching contacts of relays 58 and 59 in parallel. The operation of either one of these two relays to close its left-hand contacts will complete the connection of line 56 to the central office.

The transmitting circuit 52 includes in order, between the hybrid coil 54 and the coupler device 2, reading from left to right, an audio amplifier 60, a modulator 61, similar to the modulator 44, with associated carrier oscillator 62 for supplying thereto carrier oscillations of the high frequency

f_2, the high frequency transmitting amplifier 63 and the transmitting directional band filter 64 adapted to selectively transmit one or both single side-band products as well as the unmodulated carrier of the frequency f_2 received from the output of modulator 61. The receiving circuit 52 includes in order, between the coupler device 2 and the hybrid coil 54, reading from right to left, the directional band filter 65 adapted for selectively transmitting the speech-modulated and unmodulated carrier waves of the frequency f_{12} received over the line 1, the high frequency amplifier 66 and the demodulator 67, similar to the demodulator 50, for demodulating the applied carrier signal of frequency f_{12} to voice frequencies and for rectifying the unmodulated carrier of that frequency.

The audio amplifier 60, the high frequency transmitting amplifier 63 and the carrier oscillator 62 associated with the transmitting circuit 52 are normally deenergized. They are adapted to be energized from the power supply 68 through the parallel-connected, right-hand switching contacts of either of the two switching relays 58 and 59 when that relay is operated. The relay 58 operates in response to the rectified output current of the demodulator 67 in receiving circuit 53 when a received carrier wave of the frequency f_{12} is applied to the input of the latter demodulator; and relay 59 operates in response to the ringing current, say of 20 cycle per second, transmitted from the central office CO over the voice frequency line 56.

The complete operation of the system of the invention will now be described with reference to Figs. 1, 2 and 3.

Call between power line telephone subscriber and outside telephone subscriber.

When a telephone subscriber in the carrier system on power line 1, for example, the subscriber at station A of carrier channel 1, wishes to call a telephone subscriber outside the carrier channel to which the former subscriber is assigned, through the central office CO, he lifts his handset 31 off the switchhook 17 of his telephone set, which, in the manner previously described in connection with Fig. 3, causes the carrier oscillator 8 at his station to be energized to supply carrier oscillations of the normal carrier frequency f_{11} to the modulator 7 in the transmitting circuit 3 at the station and the carrier oscillator 14 at his station to be energized to supply carrier oscillations of the normal carrier frequency f_1 to the demodulator 13 in the receiving circuit 4 at the station. The unmodulated carrier component of the frequency f_{11} appearing in the output of modulator 7 will be amplified in the amplifier 9 and the amplified wave will be transmitted through the associated band filter 10 and the coupler device 2 to the power line 1 over which it will be transmitted to the carrier terminal CT.

The carrier waves of frequency f_{11} will pass through the coupler device 2 at the carrier terminal CT and will be selected by the directional band filter 48 in the receiving circuit 36 of carrier terminal portion CT_1. The selected carrier of frequency f_{11} will be amplified in amplifier 49 and will be rectified in demodulator 50 causing the operation of the relay 41 connected to the output of the latter. The operated relay 41 through its made left-hand contacts will close the line loop 39 to the central office CO. By any suitable connection (not shown) in the central office CO, the closing of the line loop 39 may be made to operate a lamp or other calling device to call in the central office operator. The operated relay 41 through its made right-hand contacts will also connect the power supply 51 to the carrier oscillator 45 and amplifiers 43 and 46 of the transmitting circuit 35 of carrier terminal portion CT_1 causing these apparatus elements to be energized. Carrier oscillations of the frequency f_1 will then be transmitted from the oscillator 45 to modulator 44 and the unmodulated component of frequency f_1 appearing in the output of that modulator will be transmitted through the high frequency amplifier 46, the band filter 47 and the coupler device 2 to the power line 1 over which it will be transmitted.

At each of the subscribers' stations A, B . . . on carrier channel 1, the carrier waves of frequency f_1 received over the line 1 from the carrier terminal CT will be transmitted through the coupler device 2, the receiving band filter 11, the receiving amplifier 12 and the demodulator 13, and the rectified output of the latter will cause the operation of the associated relay 22 to cause the busy signal lamp 20 to be operated from battery 21, thus indicating to the subscribers at all stations of channel 1 on the power line 1 that the latter is in use on a call.

The subscriber at station A then talks into his transmitter 5, and his speech currents after amplification in the audio amplifier 6 are combined in modulator 7 with the carrier oscillations of frequency f_{11} from oscillator 8. The resulting modulation products after amplification in the amplifier 9 will pass through the transmitting band filter 10 at the station and the coupler device 2 to the line 1 and will be transmitted over that line to the carrier terminal CT.

At the carrier terminal CT the speech-modulated carrier wave of the frequency f_{11} will pass through the coupler device 2 and will be selectively transmitted by the receiving circuit 36 of the terminal portion CT_1 and, in the manner previously described for the unmodulated carrier wave of frequency f_{11}, passes through that circuit to the demodulator 50. The demodulator 50 demodulates the carrier signals to voice frequency and a portion of the demodulated signals is transmitted through the hybrid coil 33 and the voice frequency line loop 39, held closed by the operated relay 41, to the central office CO and will be heard by the central office operator. The subscriber at station A tells the central office operator to which subscriber station outside the carrier system he wishes to be connected, and the operator in the usual manner calls the desired subscriber on the associated telephone network and sets up a talking connection through the central office CO so that the called and calling subscribers can converse with each other.

The voice signals of the called subscriber will be transmitted at voice frequencies from the central office CO over the voice frequency line 39 to the carrier terminal branch CT_1 for channel 1 and will be impressed by the hybrid coil 37 on the transmitting circuit 35. In that circuit, the called subscriber's voice signals will be amplified in the audio amplifier 43 and the amplified signals modulated in modulator 44 with the carrier oscillations of frequency f_1 from carrier oscillator 45 previously energized in response to the received unmodulated carrier of frequency f_{11}. The voice-modulated carrier of frequency f_1 in the output of that modulator will be amplified in amplifier 46 and passed through the

transmitting band filter 47 and coupler device 2 to the power line 1 and over that line to the calling station A. At the latter station, the voice-modulated carrier wave of frequency f_1 will pass through the coupler device 2 and will be selected by the band filter 11 in the receiving circuit 4. The selected carrier signals will be amplified in amplifier 12 and then combined in demodulator 13 with the carrier oscillations of the normal frequency f_1 supplied by the demodulator oscillator 14, the associated frequency change key 32 being unoperated, to demodulate the voice signals which are heard by subscriber A in his telephone receiver 15.

At the end of the call, the subscriber at station A of carrier channel 1 will hang up his handset on his hook switch 17 causing the opening of the switching contacts of the latter to disconnect the power supply from his modulator carrier oscillator 8 and his demodulator carrier oscillator 14 thus deenergizing these oscillators. The deenergization of the carrier oscillator 8 will stop transmission of the carrier wave of frequency f_{11} over the line 1. At the carrier terminal CT the relay 41 which had been held operated by carrier frequency f_{11} will release to remove power from the carrier oscillator and the amplifiers in transmitting circuit 35 so as to stop the transmission of the carrier frequency f_1 over the line, and also to open voice frequency line 39 to disconnect the central office from the branch CTi of the carrier terminal, thus returning the latter terminal to its normal unoperated condition shown and advising the central office operator to take down the connection.

The operating procedure in the case of a call from one of the subscribers' stations X, Y . . . associated with channel 2 on the power line 1 to a subscriber outside the carrier system to which the first subscriber is assigned, will be similar to that just described for a subscriber associated with channel 1 except that the normal transmitting carrier frequency f_{12} for the former station will be used in transmission from the calling station to the carrier terminal CT, instead of the carrier frequency f_{11}, and the normal receiving carrier frequency f_2 of the former stations will be used for transmitting from the carrier terminal CT to the calling station, instead of the carrier frequency f_1. The operation of the transmission and control equipment in the branch CT_2 of the carrier terminal CT in connection with such a call over carrier channel 2 will be similar to that of the corresponding equipment in carrier branch CT_1 previously described in connection with a call over carrier channel 1.

A call to a subscriber on any carrier channel of the power line 1 may be initiated by the operator at the central office CO at the request of a subscriber outside the carrier system in the following manner: It will be assumed that an outside subscriber associated with the central office CO informs the central office operator that he desires to communicate with one of the subscribers associated with channel 2 on the power line 1. The central office operator will then transmit ringing current, say of 20 cycles per second, over the two-wire line 56 to operate relay 59 connected across that line. The operated relay 59 through its made left-hand contacts will complete the connection of the line 56 to hybrid coil 54 of the carrier terminal branch CT_2 allowing this ringing current to enter the transmitting circuit 52 of that branch. The operated relay 59 through its made right-hand contacts will cause the carrier oscillator 62 and the amplifiers 60 and 63 associated with transmitting circuit 52 to be energized from power supply 68. The ringing signals entering transmitting circuit 52, after amplification in the audio amplifier 60, will be combined in the modulator 61 with the carrier oscillations of the frequency f_2 supplied from the now energized carrier oscillator 62. The resulting ringing current-modulated carrier wave of the frequency f_2 will be amplified in the high frequency amplifier 63 and transmitted out through the band filter 64 and the coupler device 2 to the line 1 over which it will be transmitted to the carrier subscribers' stations connected to that line. The portion of this modulated carrier of frequency f_2 diverted from the power line 1 by the coupler device 2 at each of the subscribers' stations X, Y . . . in the group of stations associated with carrier channel 2 will be selected by the receiving band filter 11' amplified by the amplifier 12 and will be combined in the demodulator 13 with the carrier of the frequency f_2 supplied from the associated oscillator 14 to demodulate the ringing current which will cause the operation of the associated station signal (ringer) 19 and the busy lamp 20 at the station in the manner previously described for the similar subscriber stations associated with carrier channel 1.

As the relay 59, connected across voice frequency line 56 will remain operated to send out the ringing current-modulated carrier of the frequency f_2 only during the times of application of the ringing current to that relay, the central office operator by interrupting the transmission of the ringing current at predetermined intervals in accordance with a particular code assigned to the station to be called may produce corresponding interruptions of the transmitted modulated carrier of frequency f_2 and thus of the operation of the station signal device or ringer 19 at each of the stations X, Y . . . .

The subscriber at the called station, recognizing his coded ring, answers by removing the handset 31 from the hook switch 17 at his station. This will cause his modulator oscillator 8 and his demodulator oscillator 14 to be energized. The carrier oscillations of the frequency f_{12} then will be supplied by oscillator 8 to the modulator 7 at the station, and the carrier component of the frequency f_{12} appearing in the output of that modulator will be amplified by amplifier 9, selectively transmitted by the band filter 10 and will pass through the coupler device 2 to the line 1 over which it will be transmitted to the carrier terminal CT. At the carrier terminal CT the received carrier wave of the frequency f_{12} will pass through the coupler device 2 and will be selectively transmitted by the band filter 65 in the receiving circuit 53 in carrier terminal branch CT_2. The selected carrier of frequency f_{12} after amplification in the amplifier 66 will be rectified in the demodulator 67 and will cause the operation of the associated relay 58. The operated relay 58 through its made left-hand contact will close the transmission line loop 56 to the central office 57, this loop having been reopened by the release of the relay 59 with the cessation in the supply of ringing current from the central office CO. The operated relay 58 through its made right-hand contacts will simultaneously connect the power supply 68 to the carrier oscillator 62 and the amplifiers 60 and 63 in the transmitting circuit 52, for energizing this equipment so that a carrier wave of the frequency f_2 will be transmitted out over the line 1, thus setting up the

system for two-way conversation between the calling and called subscribers through the line 1, the branch CT_2 of the carrier terminal CT, the line 56 and the central office CO.

The conversation of the subscriber at the called station of channel 2 on the power line 1 will be transmitted over that line to the carrier terminal CT as modulations of the transmitted carrier of the frequency f_{12} at the carrier terminal where the carrier signals will be demodulated to voice frequencies by the demodulator 67 in the receiving circuit 53 and will be transmitted at voice frequencies through the hybrid coil 54, the voice frequency line 56 and the central office CO to the calling subscriber. The conversation of the calling subscriber will pass at voice frequencies through the central office CO and over the line 56 to carrier terminal branch CT_2, and through the hybrid coil 54 into the transmitting circuit 52 of that carrier terminal branch. These voice signals will be modulated in modulator 61 in that circuit with the carrier of frequency f_2 from oscillator 62, and the voice-modulated carrier of that frequency in amplified form will be transmitted to the power line 1 and out over that line to the called subscriber in the manner previously described.

Call between two power line carrier subscribers' stations

To make a party line or reverting call, say to the subscriber's station B on channel 1 of the power line 1, the subscriber at station A of that channel first determines by the condition of his busy lamp 20 whether his own channel is busy. If his channel is idle as indicated by the non-lighted condition of his busy signal lamp 20, subscriber A, without removing handset 31 from the hook switch 17, presses the non-locking key 32 on his communication set which, in the manner previously described in connection with Fig. 3, causes additional condensers to be connected into the frequency-determining circuits of his carrier oscillators 8 and 14 to shift the tuning of these oscillators from frequency f_{11} to f_{12} and from frequency f_1 to f_2, respectively, the changed frequencies corresponding to the transmitting and receiving frequencies, respectively, employed on carrier channel 2, and to change the connections at the station to connect the appropriate band filters 10' and 11' in the transmitting and receiving circuit, respectively, at the station in place of the band filters 10 and 11. If channel 2 at the time is also idle, the subscriber's busy signal lamp 20 will remain unlighted due to the absence of the carrier frequency f_2 on the power line. Subscriber A then lifts his handset 31 off the switchhook 17, which, by completing a locking circuit for relay 33, locks his communication set on the alternate frequency assignment. The subscriber A may then release his key 32. The carrier frequency f_{12} appearing in the output of modulator 7 will be transmitted through the band filter 10' to the line 1.

A portion of the carrier wave of frequency f_{12} diverted from the line 1 at the carrier terminal CT through the coupler device 2 will be selectively transmitted by the band filter 65 in the receiving circuit 53 of branch CT_2 of the terminal. The selected carrier of frequency f_{12} will be amplified in amplifier 66 and rectified in the modulator 67 to cause the operation of the associated relay 58. The operated relay 58 closes the line loop 56 to the central office CO to call in the central office operator and also causes energizing current to be supplied from power supply 68 to the carrier oscillator 62 and the amplifiers 60 and 63 associated with the transmitting circuit 52 of carrier branch CT_2, so that a carrier wave of the frequency f_2 is transmitted out over that circuit to the line 1 over which it will be transmitted to the subscribers' stations. A portion of the carrier wave of frequency f_2 will be diverted from the power line 1 through the coupler device 2 at each of the subscriber's stations X, Y . . . associated with channel 2, will be selected by the receiving band filter 11' normally associated with the receiving circuit 4 in each of these stations, amplified in amplifier 12 and rectified in demodulator 13 to cause the operation of relay 22 to operatively energize the busy signal lamp at 20, so as to indicate by the lighted conditions of the busy lamps to the subscribers on channel 2 that the channel is busy in connection with a call.

The calling subscriber at station A by talking into his transmitter 5 then modulates the transmitted carrier wave of frequency f_{12} in modulator 7 with his voice signals, and the voice-modulated carrier wave of that frequency after amplification in the amplifier 9 will be transmitted through band filter 10' and coupler device 2 to the line 1 over which it will be transmitted to the carrier terminal CT and will pass through the coupler device 2 at that terminal to the demodulator 67 in the receiving circuit 53 of carrier terminal branch CT_2 in the manner previously described for the unmodulated carrier of that frequency. The demodulator 67 will demodulate the received carrier signals to voice frequencies, which will be transmitted through the hybrid coil 54 and voice frequency line 56 to the central office CO. The central office operator then rings station B, as requested by the subscriber at station A, in the manner previously described in connection with a call from an outside subscriber. The called subscriber B, on operation of the signal device (ringer) 19 at his station to provide the signal assigned to his station, answers by lifting the handset 31 off the switchhook 17 in his communication set, causing his carrier oscillators 8 and 14 to be energized to transmit carrier oscillations of the normal carrier frequencies f_{11} and f_1 to the modulator 7 in his transmitting circuit 3, and to the demodulator 13 in receiving circuit 4, respectively.

The unmodulated carrier component of frequency f_{11} appearing in the output of the modulator 7 at the called station B is transmitted through the band filter 10 normally associated with the transmitting circuit 3 at the station to the line 1 and out over the line to the carrier terminal CT. At that terminal, in a manner similar to that described previously in connection with a call to an outside subscriber through the central office CO, the received carrier of frequency f_{11} serves to signal the central office operator, and to energize the transmitting circuit 35 in the carrier terminal branch CT_1 so that it sends out over the line 1 the carrier wave of the frequency f_1 which is the normal receiving carrier frequency of the subscribers' stations associated with carrier channel 1. A portion of this unmodulated carrier of frequency f_1 is diverted from the power line 1 at each of the stations A, B . . . associated with channel 1 through a coupler device 2 and is selectively transmitted by the band filter 11 normally associated with the receiving circuit 4 in each of these stations. The selected carrier of frequency f_1 in the output of the band filter 11 after amplication in the am-

plifier 12, is rectified in the demodulator 13 to cause operation of the relay 22 associated with the output of the demodulator which in turn causes the busy signal lamp 20 to be energized in a manner previously described to indicate to the subscriber at the station that channel 1 of the power line is being used on a call.

The central office operator on the operation of his signaling device indicating that the subscriber at station B has answered, completes a talking connection through the central office CO between the voice frequency lines 56 and 39 so that the subscribers A and B on channel 1 can converse with each other.

The voice signals of the calling subscriber at station A normally assigned to channel 1 are transmitted as modulations of the alternate transmitting carrier frequency f_{12} from the output of modulator 7 at that station out over the line 1 to the carrier terminal CT and through the receiving circuit 53 of carrier terminal branch CT_2 to the demodulator 67 in that circuit; at voice frequencies from the output of that demodulator through hybrid coil 54 and voice frequency line 56 to the central office CO and from that office over voice frequency line 39 to the modulator 44 in the transmitting circuit 35 of the carrier terminal portion CT_1; and from the output of the latter modulator as modulations of the carrier frequency f_1 out over the line 1 to the demodulator 13 in the receiving circuit 4 of the called subscriber's station B. A's demodulated voice signals in the output of that demodulator are transmitted to the telephone receiver 15 and are heard by subscriber B.

The voice signals of the called subscriber B normally assigned to channel 1, however, are transmitted as modulations of the normal transmitting carrier frequency f_{11} of his station from the output of modulator 7 at station B out over line 1 to the carrier terminal CT and at that terminal to the demodulator 59 in the receiving circuit 36 of carrier terminal branch CT_1; at voice frequencies from the output of the demodulator 50 through the hybrid coil 37 and voice frequency 39 the central office CO, and from the central office through the voice frequency line 56 and hybrid coil 54 to the modulator 61 in the transmitting branch 52 of the carrier terminal branch CT_2; and from the output of that modulator as modulations of the transmitted carrier frequency f_2, which is the alternate receiving carrier frequency of the calling subscriber A, to the line 1 and over that line to the demodulator 13 in the receiving circuit 4 of the calling subscriber's station A. The demodulated signals of subcriber B appearing in the output of demodulator 13 at subscriber station A passes to the associated telephone receiver 15 and are heard by subscriber A.

When the call between subscriber stations A and B is completed, both subscribers hang up their desk sets 31 on switch-hook 17 of their communication sets. This automatically deenergizes the carrier oscillators 3 and 14 of both sets, stopping the transmission of the carriers f_{11} and f_{12} over the line 1 so as to signal the central office operator to pull down the previous connection; reverts the tuning of the oscillators at the calling station A to the frequencies, f_{11} and f_1 of channel 1 to which that station is normally assigned, and deenergizes the change-over relay circuits R_1 and R_2 at that station to switch the filter connections back to normal.

No mention has been made previously of the loss pad 68 inserted in the connection between the coupler device 2 and the band filters 10, 10', 11 and 11' at subscriber station A. This pad is provided to insert a fixed amount of loss between subscriber station A and the carrier terminal CT, because of the closer proximity of that station to the carrier terminal than the other subscriber stations, so as to maintain substantially the same amount of net loss between the carrier terminal and each subscriber's set on the system. Loss pads of suitable values may be inserted in the connections to each of the other subscriber's stations also, if required to accomplish the above purpose.

Some of the advantages of the carrier arrangements of the invention are outlined below:

1. No modifications in the switchboard at the central office are required. All switchboards, whether dial or magneto, include provisions whereby closure of the loop in accordance with switchhook (or dial) operations will perform all the functions required.

2. No sequence operations in the carrier terminal are required to differentiate between a straight (outside) call and a party line call, thus resulting in a saving in equipment and simplification in operating procedure.

3. The subscriber's set at each subscriber's station operates only in conjunction with a carrier terminal so that loss pads can be provided with sets close to the carrier terminal to permit a fixed net loss between the carrier terminal and each subscriber's set on a carrier channel. Thus, it will not ordinarily be necessary to provide AVC (automatic volume control) arrangements either in the subscriber sets or carrier terminals. However, it is within the scope of the invention to provide such AVC arrangements in connection with the amplifier at each of the subscriber's sets or carrier terminals if desired.

4. It permits a large reduction in selectivity requirements because:

(*a*) Due to the loss pad arrangement outlined above, there will be no large level difference at any point on a line between the outputs of the various subscriber sets on several channels associated with the line. Thus, crosstalk requirements between channels going in the same direction on the line can be minimized to the point where equal level crosstalk only is involved;

(*b*) For all channels on the line, the channels going in one direction, that is, from the carrier terminal to the subscriber, can be grouped in one frequency range and the channels going in the opposite direction, from subscribers to the carrier terminal, can be placed in another frequency range, thus affording larger frequency separation for conditions where opposite directional transmission is involved.

Various modifications of the carrier arrangements illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. In a carrier communication system, a wave transmission medium, a central station including at least two carrier terminals connected to said medium, operating on different carrier frequencies to transmit communication signals to and receive communication signals from said medium, a plurality of carrier subscriber stations connected to said medium, each of one group of said subscriber stations normally operating to transmit communication signals to and to re-

ceive communication signals from said medium on the receiving carrier frequency and the transmitting carrier frequency, respectively, of one of said carrier terminals, each of a second group of said subscriber stations normally operating to transmit communication signals to and to receive communication signals from said medium on the receiving carrier frequency and the transmitting carrier frequency, respectively, of another of said carrier terminals and means to enable communication without appreciable distortion between any two subscriber stations in either group comprising means at each subscriber station in each group for changing the station transmitting and receiving carrier frequencies to those of said other group and means for interconnecting the carrier terminals of the two groups so that the signals received by each carrier terminal over said medium on the receiving carrier frequency of that terminal are supplied to the other carrier terminal for retransmission thereby on its normal transmitting carrier frequency over said medium.

2. In a carrier communication system, a transmission medium, a plurality of two-way carrier channels applied to said medium, a different group of two-way subscriber carrier communication stations and an individual two-way carrier terminal station being associated with each of said channels, a central switching office associated with said medium separately through said individual carrier terminal stations, each of said carrier channels normally utilizing carrier waves of different frequencies, different for each channel, for the communication signals transmitted in opposite directions between its carrier terminal station and its subscriber stations and means to enable communication without appreciable signal distortion between any two of said subscriber stations associated with the same carrier channel comprising means at one of said two stations under control of the subscriber thereat for changing its transmitting and receiving carrier frequencies to those normally utilized by the subscriber stations associated with another carrier channel and means under control of said central office for connecting the carrier terminal station of said other channel to the carrier terminal station of said same carrier channel so as to supply the communication signals received by each carrier terminal station from said medium to the other for transmission thereby on its normal transmitting carrier frequency over said medium.

3. In a carrier wave communication system, a transmission medium, a plurality of groups of subscriber carrier communication stations and a corresponding number of two-way carrier terminals connected to said medium, one group of said subscriber stations and one of said carrier terminals associated with one carrier channel on said medium normally utilizing one carrier frequency for transmission in one direction between each subscriber station in that group and said one carrier terminal and a second carrier frequency for transmission in the opposite direction therebetween, a second group of said subscriber stations and a second of said carrier terminals associated with a second carrier channel on said medium normally utilizing a third carrier frequency for transmission in one direction between each subscriber station in the group and said second carrier terminal and a fourth carrier frequency for transmission in the opposite direction therebetween, a common central switching office associated with said medium separately through the carrier terminal station for each carrier channel and means to enable two-way communication without appreciable signal distortion between any two subscriber stations normally associated with the same carrier channel comprising means under control of the subscriber at the one of said two stations calling the other for changing the carrier transmitting and receiving frequencies of said one station only to those normally utilized by the subscriber stations of another channel, and means under control of said central switching office for setting up a connection between the carrier terminal stations for said same and said other channel such that the communication signals received by each from said medium are retransmitted by the other on its normal carrier transmitting frequency over said medium.

4. In a carrier communication system, a transmission medium, a central station including at least two two-way carrier terminals, a plurality of two-way carrier substations connected to said medium, each of said carrier terminals operating on respectively different carrier frequencies for transmission to and from said medium, one group of said carrier substations normally operating on the carrier frequencies of one of said carrier terminals for transmission to and from said medium, another group of said carrier substations normally operating on the carrier frequencies of another of said carrier terminals for transmission to and from said medium and means for changing the operating frequencies of any substation in one of said groups to the normal operating frequencies of the substations in another of said groups to enable communication through said central station between substations in the same group.

5. In a carrier communication system, a transmission medium, a plurality of groups of subscriber's two-way carrier communication sets and a corresponding number of two-way carrier terminal sets connected to said medium, a common central switching office for said subscriber sets adapted for connection to said medium through each of said carrier terminal sets, each set of one group of said subscriber sets being normally conditioned under control of the subscriber to transmit to said medium on a carrier of one frequency and to receive therefrom on a carrier of a second frequency, each set of a second group of said subscriber sets being normally conditioned under control of the subscriber to transmit to said medium on a carrier of a third frequency and to receive therefrom on a carrier wave of a fourth frequency, one of said carrier terminal sets being conditioned to receive from said medium on a carrier of said one frequency, and to transmit thereto, under control of said central office or a received carrier of said one frequency, on a carrier of said second frequency, a second of said carrier terminal sets being conditioned to receive from said medium on a carrier wave of said third frequency and to transmit thereto, under control of said central office or a received carrier of said third frequency, on a carrier wave of said fourth frequency, and additional means in each subscriber set in said one and said second group under control of the subscriber to change the transmitting and receiving carrier frequencies of the set to the normal transmitting and receiving carrier frequencies of the subscriber sets in the other group.

6. The system of claim 5, in which said common central office is normally disconnected from

said medium and each of said carrier terminal sets includes switching means under control of said common central switching office or of a received carrier of the frequency on which it is conditioned to receive, to connect said central office to said medium through that carrier terminal set.

7. The system of claim 5, in which each of said carrier terminal sets includes means for demodulating the communication signals from the carrier of the frequency which it is conditioned to receive, incoming over said medium, for transmission to said central office and means for modulating signals from said central office on the carrier transmitted by the set to said medium.

8. In combination in a carrier communication system, a wave transmission medium, a plurality of two-way carrier communication channels on said medium, a plurality of groups of subscriber two-way carrier communication stations and a corresponding number of two-way carrier terminals connected to said medium, a common central switching office connected to said medium through each of said carrier terminals, one group of said subscriber stations and one of said carrier terminal stations being associated with one of said carrier channels, another group of said subscriber stations and another of said carrier terminals being associated with another of said carrier channels, and means to enable two-way communication between two subscribers stations in the same group through said central office comprising means at each subscriber station in said one and said other group under control of the local subscriber for shifting its transmitting and receiving carrier frequencies to those of the subscriber stations in a different group.

9. In combination in a carrier communication system, a wave transmission medium, a plurality of subscriber two-way carrier communication sets and a plurality of two-way carrier terminal sets connected to said medium, a common central switching office for said subscriber sets connected to said medium through each of said carrier terminal sets, each of one group of said subscriber sets being normally adapted to transmit

communication signals to said medium on a carrier wave of one frequency and to receive communication signals therefrom on a carrier wave of a second frequency, each of another group of said subscriber sets being normally adapted to transmit communication signals to said medium on a carrier wave of a third frequency and to receive communication signals therefrom on a carrier wave of a fourth frequency, one of said carrier terminal sets being adapted to selectively receive carrier waves of said one frequency incoming over said medium, to demodulate the communication signals therefrom for transmission to said central office and to transmit communication signals received from said central office to said medium on a carrier wave of said second frequency, a second one of said carrier terminal sets being adapted to selectively receive carrier waves of said third frequency incoming over said medium, to demodulate the communication signals therefrom for transmission to said central office and to transmit communication signals received from said central office to said medium on a carrier wave of said fourth frequency and each subscriber set in said one and said second group also including means under control of the local subscriber for changing the transmitting and receiving carrier frequencies to those normally used by the subscriber sets in the other group to enable two-way communication through said central office and said one and said second carrier terminal sets between subscriber sets in the same group.

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