Dec. 2, 1941. H. R. MOORE 2,264,397

POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

Filed Oct. 22, 1940 3 Sheets-Sheet 1

FIG. 1

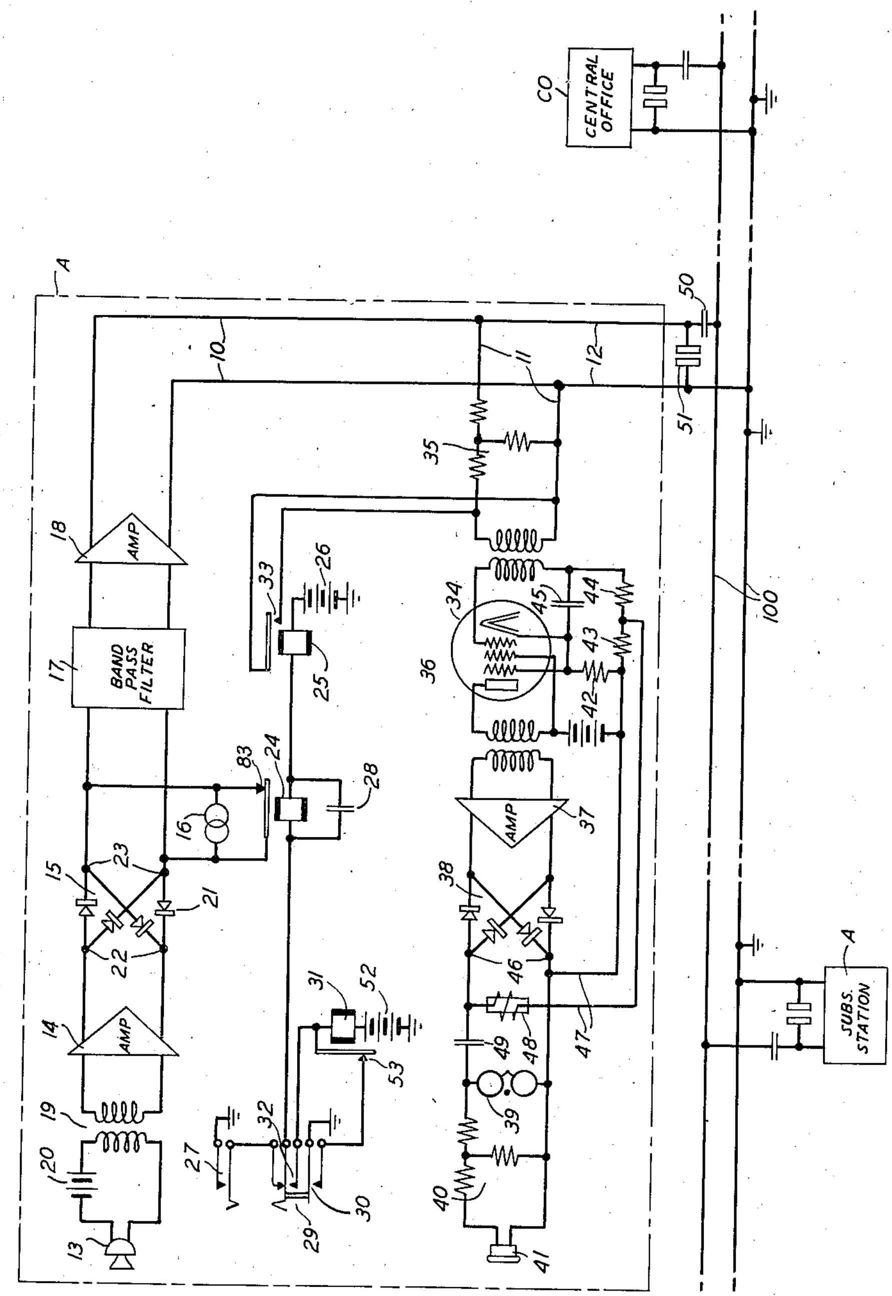

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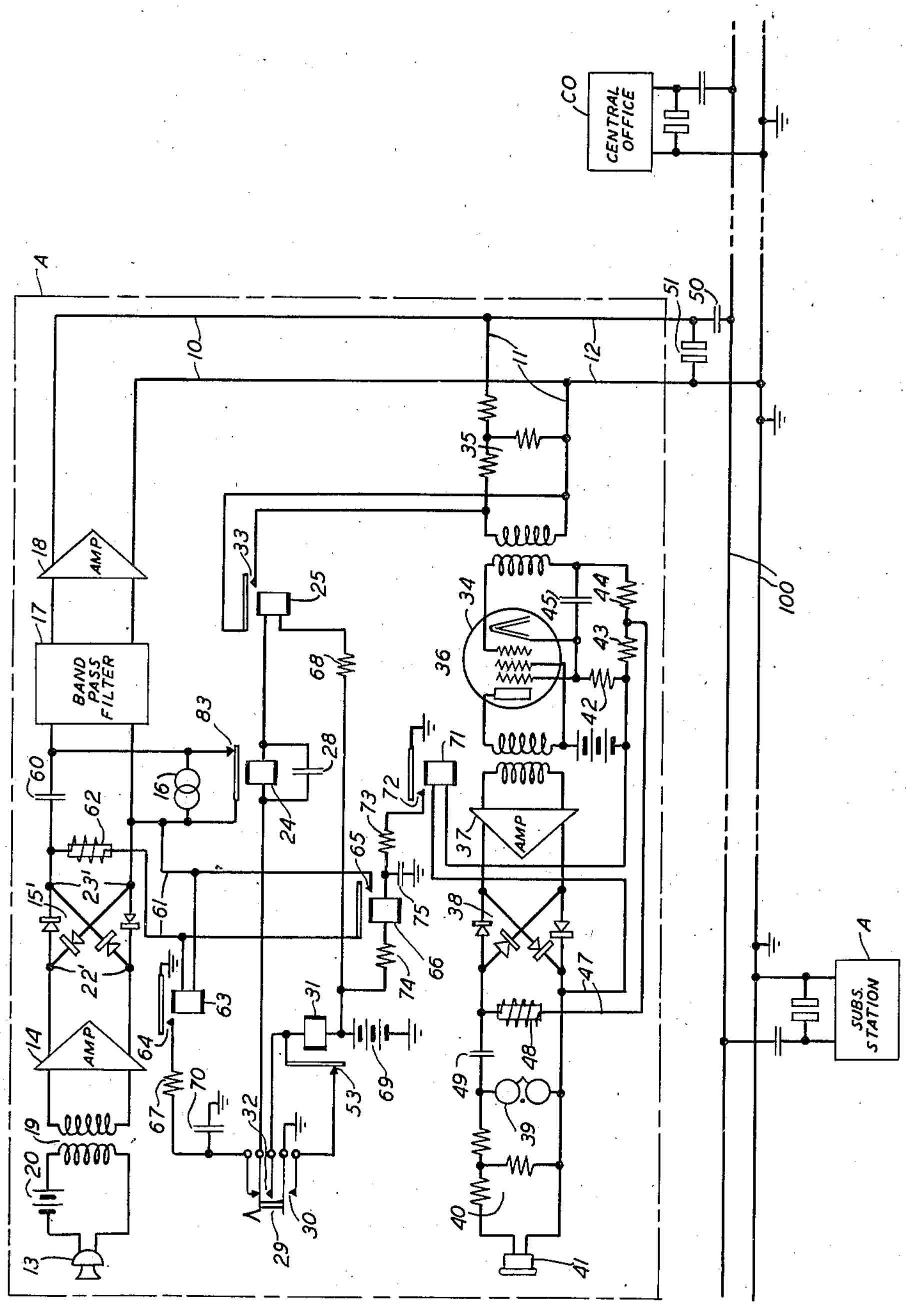
FIG. 2



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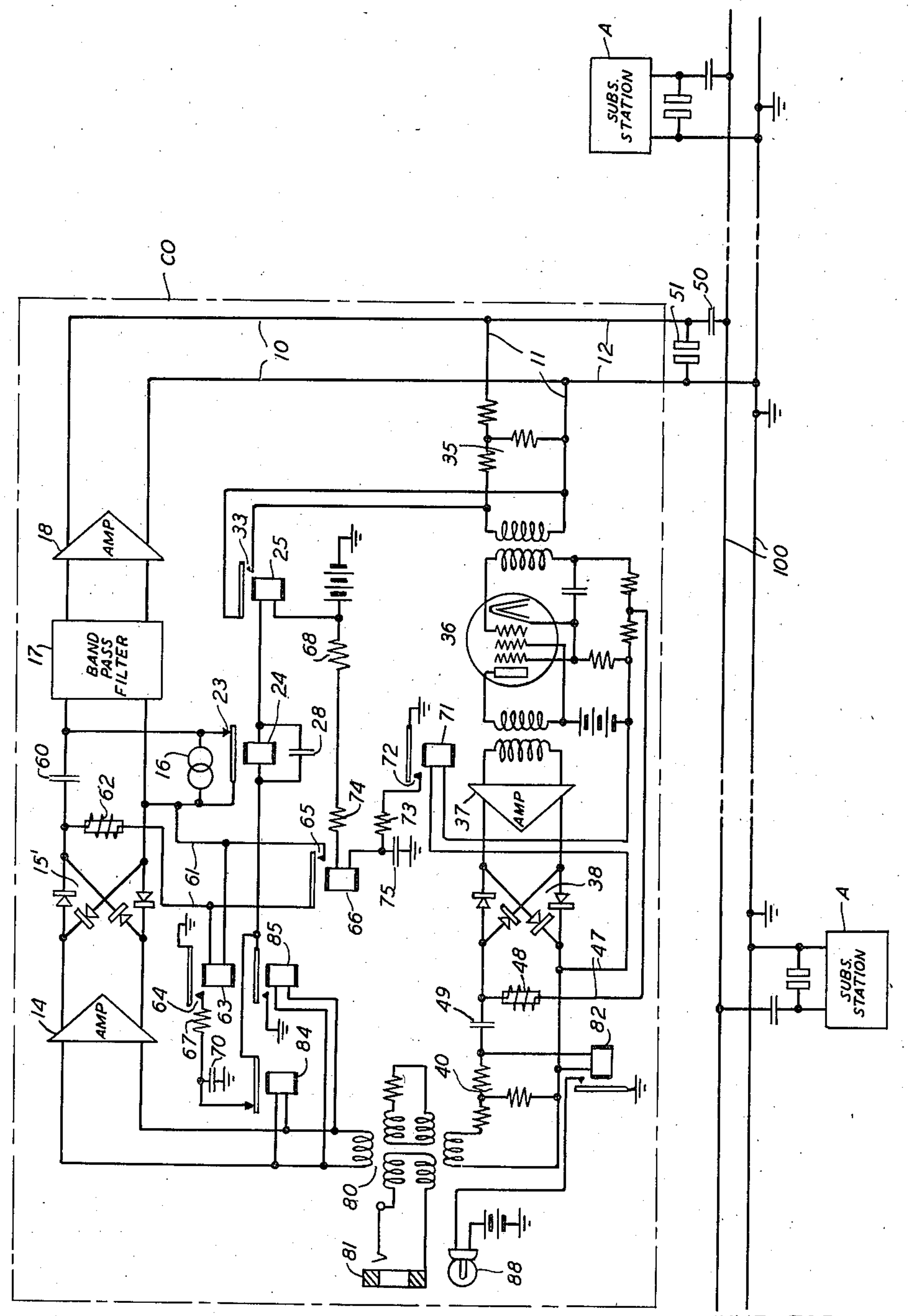

FIG. 3

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POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

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Application October 22, 1940, Serial No. 362,245

10 Claims. (Cl. 179—2.5)

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

Carrier frequency telephony over transmission lines primarily intended for transmission of low frequency high voltage electric power is, of course, well known. In such a system, the telephone subscriber's station coupled to the power line usually comprises a radio frequency or carrier wave transmitting circuit and a radio frequency or carrier wave receiving circuit. When a single carrier wave is used for transmitting and receiving, these circuits are arranged such that the receiving circuit is normally enabled, that is, in condition to receive incoming transmission and the transmitting circuit is normally disabled, that is, rendered ineffective for outgoing transmission purpose. When outgoing transmission is desired, the transmitting circuit is enabled and the receiving circuit simultaneously disabled.

An object of this invention is to improve and to simplify the circuit and means required in such a system for enabling and disabling the transmitting and receiving circuits.

A more complete understanding of the invention will be obtained from the detailed description which follows, read in connection with the appended drawings, wherein:

Fig. 1 shows a part of a power line carrier frequency telephone system with one telephone station shown in detail;

Fig. 2 shows a modification of the telephone station of Fig. 1; and

Fig. 3 shows the circuit arrangement for the central office of the system of Figs. 1 and 2.

Fig. 1 shows a portion of a power line carrier frequency telephone system comprising a power line 100, a plurality of subscriber's telephone stations A, one of which is shown in detail, and a central office CO for the system. Each station may communicate directly with the other stations in the system and with the central office. The line is shown as a single phase power line with grounded neutral, although it could be an insulated single phase line, or comprise a pair of phase wires of a multiphase power line, or other type of power line.

The telephone station comprises a transmitting circuit 10 and a receiving circuit 11 constituting branches of the line 12 coupling the station to the power line. The transmitting circuit comprises a transmitter 13, for example, of the carbon granule type, a volume control amplifier 14, a modulator 15, a high frequency or carrier wave oscillator 16, a band-pass filter 17 and an output amplifier 18. The transmitter is connected to the volume control amplifier through a transformer 19, and is connected in series with one transformer winding and a source 20 of talking current. The volume control amplifier may be of the voice operated gain adjusting or volume limiter type, or may be provided with a manual control, to provide for talkers of different transmission levels so that the voice currents level into the modulator will be of the same order at all times. The modulator may comprise a plurality of asymmetric resistance devices 21, such as copper-copper oxide rectifier units arranged in a bridge configuration, the voice currents being impressed across terminals 22 and the carrier wave being impressed across terminals 23. The modulator resistance devices are arranged such that during one half of each cycle of the carrier wave, a low resistance path for the voice current is provided through the side elements, and during the other half cycle through the lattice elements. With the arrangement shown, the carrier wave is not suppressed and is transmitted with the modulation products to the filter. The filter selects the modulation products it is desired to transmit. It may be designed to pass the carrier frequency and the sum frequencies or upper side-band, that is, F to $F+F_1$, where F_1 is the upper limit of the voice frequencies it is desired to transmit, or to pass the carrier frequency and the difference frequencies or lower side-band F to $F-F_1$, or to pass both side-bands, that is F to $F\pm F_1$. The amplifier 18 may be of any suitable type, and amplifies the carrier wave and modulation products to a desired level before they are impressed on the power line. Normally, that is, when the subscriber at station A is not using his equipment, the oscillator is short-circuited by the normally closed contact 83 of relay 24. The winding of relay 24 is connected in series with the winding of a second relay 25, a source 26 of current and the normally open key or button 27. Closure of key 27 completes through ground the operating circuit for relays 24 and 25, to open contact 83 and to close contact 33 of relay 25. The condenser 28 connected in parallel with the winding of relay 24 delays the operation of the latter sufficiently to permit relay 25 to operate first when key 27 is closed. The subscriber closes key 27 when he wishes to talk. The relays 24 and 25 are connected to a second or signal key 29, operation of which completes through its lower contact 30 a circuit for an interrupter 31, and through its upper contact 32 a circuit connecting the relays 24 and 25 in series with the winding of, and the current source for, the interrupter 31 and to ground.

The receiving circuit comprises an attenuator network 35, a gain control amplifier 36, a source 37 of additional amplification, if desired, a demodulator 38, station signalling means 39, a second attenuation network 40 and a conventional telephone receiver 41. When the normally open contact 33 of relay 25 closes on operation of relay 25, the receiving circuit is short-circuited. Attenuator 35 may comprise any suitable network that introduces sufficient impedance between the coupling line 12 and the short circuit provided by the relay 25, to constitute a high impedance to transmission outgoing from the station. The amplifier 36 may comprise an electron discharge device 34 whose input control grid biasing potential is determined by the potential drop in the cathode resistor 42, and in the resistor 43 which is supplied with the direct current component of the output of the demodulator. Variation in the output level of the demodulator from a preassigned level varies the value of the current fed back to the resistor 43 through the connection 47, to vary the bias on the control grid of the device 34, to change the gain of the control amplifier and to restore the demodulator output to its preassigned level. The variation in the modulator output may result from change in the level of the transmission incoming to the station because of different distances between any one station and the other stations coupled to the power line. The resistance 44 and condenser 45 suppress alternating current feedback in the controlled amplifier. The demodulator is of the same type as the modulator, comprising a plurality of asymmetric resistance devices such as copper-copper oxide rectifier units in bridge configuration. As indicated above, the gain control resistor 43 is connected across the terminals 46 of the demodulator through connections 47, a retard coil 48 being provided in one connection. Condenser 49 is a blocking condenser. The station signalling means 39 is shown as a ringer connected across the output circuit of the modulator. The network 40 compensates for the lower volume level required for listening, as compared with that required for operation of the signalling means 39.

The station is connected to the power line 100 by the coupling line 12, one conductor of the latter being connected directly to the grounded wire, and the other to the non-grounded wire through a coupling condenser 50. With an insulated single phase line, or in case of a connection to a pair of phase wires of a multiphase system, a coupling condenser would be provided in each conductor of the coupling line. Coupling might also be accomplished by use of a power distribution transformer, for example, in the manner described and claimed in L. K. Swart application Serial No. 358,879, filed October 5, 1940. In any case, a suitable protector 51 is provided to safeguard the subscriber and the station equipment against the hazard of the high voltage on the power line.

The method of operation of the station will now be described. In the normal condition of the station or central office, the transmitting circuit is disabled and the receiving circuit is enabled, that is, the station is arranged for the receiving of incoming transmission, but not for the generation of outgoing transmission to be applied to the power line. Operation of the signal key 29 completes the circuit for the interrupter 31 from ground, battery 52, winding of interrupter 31, normally closed contact 53, contact 30 to ground. The make and break of contact 53 alternately closes and opens the battery circuit for relays 24 and 25, this circuit being battery 26, relay 25, relay 24, contacts 32, 53 and 30 to ground. Energization of relay 24 opens contact 33. As long as the key 29 is depressed, relay 24 pulses in accordance with the make and break of the interrupter, for example, vibrating at 20 cycles per second, and the output of the modulator is modulated at that rate. Relay 25 is also operated, the short circuiting or disabling of the receiving circuit during each pulse preventing annoyance to the subscriber if he should be listening while signaling, and also eliminating the possibility of singing through the electrical-acoustical path around the transmitting and receiving branches of the station. The signal modulated carrier wave is transmitted to the filter 17, amplified in amplifier 18 and impressed on the power line 100. The signal modulated carrier wave is detected at each subscriber station coupled to the line and at the central office. The signal modulated carrier passes through the receiving circuit amplifiers 36, 37, is demodulated, and the low frequency signal operates the signaling means 39. Differentiation between stations and the central office would be by code, the signaling key being depressed and lifted the number of times as required by the code for calling the particular station desired by the calling subscriber.

Let it be assumed that the called party has answered. Transmission from the calling subscriber may now take place. The calling subscriber depresses the key 27, causing relays 24 and 25 to operate. The short-circuit is removed from the oscillator and a short circuit is placed on the receiving circuit. The condenser 28 delays operation of relay 24 so that relay 25 operates first, preventing annoying clicks in the receiver from the initiation of the outgoing carrier waves. Actuation of the transmitter 13 by voice or sound waves produces corresponding alternating currents in the winding of transformer 19, which currents are impressed on the modulator input terminals after suitable amplification in amplifier 14. The voice frequency currents are modulated on the carrier wave in the modulator. The unsuppressed carrier wave and the products of modulation are transmitted to the band-pass filter. The frequency band passed by the filter is amplified in amplifier 18, and transmitted to the line, over which it is transmitted to the called station. When both side-bands are being transmitted, the filter 17 might be omitted but its retention is desirable to prevent possible overloading of other parts of the system by unwanted modulation products. In some cases, transmission of the single side-band only of the modulated carrier is desirable to insure avoidance of phase cancellation effects that would arise in the demodulation of the upper and lower side-band frequencies should their averages phase delays in transmission differ by odd multiples of 90 degrees from the phase delay of the carrier wave.

When the calling subscriber ceases to talk, he releases the key 27 so that relays 24 and 25 are deenergized, thereby disabling the transmitting circuit and enabling the receiving circuit. Until the calling subscriber does this, the called subscriber, or any other subscriber on the power line, is unable to break in since the receiving circuit is short-circuited. On the assumption that relay 25 has been deenergized, incoming transmission from the called party, or the central office if the latter has been signaled by the calling subscriber, has ingress to circuit 11 from the coupling line 12, and is received as single or double side-bands of the modulated carrier wave together with the carrier wave itself. The incoming waves are amplified in amplifiers 36 and 37, demodulated by demodulator 38, and the voice frequency currents are translated by the receiver into the sound waves impressed on the transmitter at the other station.

Fig. 2 shows a somewhat similar arrangement to that of the subscriber's telephone station of Fig. 1, differing principally in the omission of the depress or push-to-talk key and its replacement by voice-operated means to enable the transmitting circuit, and in the provision of voice-operated means in the receiving circuit to disable the transmitting circuit enabling means during a period of incoming transmission to the station, that is, after the other party has started to talk. Like parts in the circuits of Figs. 1 and 2 bear corresponding identifying characters. The modulator 15' of Fig. 2 has its variable resistance units or devices arranged so that a rectified component of the voice currents impressed across terminals 22' appears across terminals 23'. Blocking condenser 60 keeps this direct current out of the oscillator and confines it to a path including connections 61, retardation coil 62 and the relay 63 connected across the modulator output. A normally open contact 64 is associated with relay 63. The connection 61 extends, also, to the normally open contact 65 associated with a relay 66. When the relay 63 is energized, the contact 64 closes to complete a discharge circuit for a condenser 70 connected between one terminal of the resistance 67 and ground, and normally charged from battery 69.

A relay 71 is connected in series with one of the connections 47 of the feedback path in the receiving circuit and has a normally open contact 72 associated therewith. When relay 71 is energized, contact 72 is closed to complete a discharge circuit for condenser 75, which is connected between ground and one terminal of a resistance 73 and which is normally under charge from battery 69. Discharge of the condenser 70 through resistance 67 causes relays 24 and 25 to operate, and discharge of condenser 75 through resistance 73 causes relay 66 to operate, with resulting opening or closing of their associated contacts.

As shown in Fig. 2, the subscriber's station circuit is in its normal condition, that is, the transmitting circuit is disabled for transmission purposes and the receiving circuit is enabled or in condition to receive incoming telephonic signals. If it is assumed that the subscriber at the station wishes to call another station on the line, or to call the central office, the operations are as follows: The calling party signals the desired party in accordance with the signalling code for the system by depressing the signal key or button 29 the prescribed number of times. This results, as in the circuit of Fig. 1, in the energization of relays 24 and 25 and the interrupter 31, whereby the relay 24 is caused to pulse and to modulate the output of the oscillator in accordance with the interrupter frequency. The signal modulated carrier wave is passed by the filter, amplified in amplifier 18, and applied to the power line through the coupling line 12.

Let it be assumed that the called party, or the operator, has answered. The key 29 having been released at the conclusion of the signaling operations, the station circuit would be as shown in Fig. 2. When the subscriber talks into the transmitter, audio frequency currents corresponding to the sound waves are generated in the transformer winding, amplified in amplifier 14, and impressed across the terminals 22' of the modulator 15'. The voice currents are rectified, and the resultant direct current flows through the connections 61 to energize relay 63. This causes contact 64 to close, completing a discharge circuit for condenser 70 through resistance 67 and contact 64. This causes relays 24 and 25 to operate, enabling the transmitting circuit by opening contact 83 to remove the short circuit on the oscillator 16, and disabling the receiving circuit by closure of the short-circuiting contact 33. The voice currents are modulated on the carrier wave and, as in the case of the circuit of Fig. 1, the carrier wave and the preassigned side-band or side-bands are transmitted through the filter and the output amplifier to the power line and over the latter to the other station. When the subscriber at the calling station stops talking, relay 63 deenergizes, contact 64 is restored to its normal condition, condenser 70 is again charged through resistance 68 and relays 24 and 25 from battery 69, holding relays 24 and 25 operated for a short hold-over period, thereby preventing the clipping of weak intermediate and ending syllables of speech. In situations where it might be more desirable to employ a modulator such as that of Fig. 1 rather than the modulator 15', the relay 63 could be operated, of course, by the output of an amplifier-detector connected across the input to the modulator. Incoming transmission from the called party is received as in the case of the circuit of Fig. 1, but the enabling means for the transmitting circuit is disabled during such receiving by the operation of relays 66 and 71. Current fed back to the resistor 43 of amplifier 34 for gain control purposes, energizes the relay 71 and causes contact 72 to close. The relay 66 is energized by the discharge of condenser 75 through the resistance 73 to ground, resistances 73 and 74 and condenser 75 corresponding in function to resistances 67 and 68 and condenser 70. The closure of contact 65 short-circuits relay 63 and prevents disabling of the receiving circuit during incoming transmission which might otherwise result through operation of the transmitting circuit enabling means because of sound waves resulting from a cough or other acoustic disturbance in the vicinity of the calling party's transmitter. When incoming transmission ceases, the relay 71 deenergizes and contacts 72 and 65 are restored to their normal conditions, and the transmitting circuit is available for further use by the calling party. When the call has been terminated, the circuit at the station will be in the condition shown by Fig. 2.

Fig. 3 shows the circuit for the central office of the system through which the power line system subscribers may call one another, or be connected with another telephone system. It is substantially the same in arrangement and operation as the circuit of Fig. 2 except for those differences that will now be specified. The transmitting and receiving circuits terminate in windings of a hybrid coil 80 instead of in a transmitter and a receiver, but the operator may connect her operator's set (not shown) with these circuits by plugging into the two-wire operator's line jack 81. The signaling means 39 is replaced by a low frequency, for example, 20 cycles per second, relay 82 controlling a circuit for a switchboard signal lamp 88. The principal difference over the circuit of Fig. 2 is in the outgoing signaling means and circuit. Low frequency, for example, 20 cycles per second, relays 84 and 85 are connected across the transmitting circuit ahead of the amplifier 14 and are adapted to be operated on signaling current supplied by the operator through the operator's jack.

If it is assumed that a subscriber has signaled to the operator, she responds by plugging into the line jack, and employing her cord circuit for talking and listening. While she speaks, relay 63 is operated as are relays 24 and 25, as in the circuit of Fig. 2, enabling the transmitting circuit and disabling the receiving circuit. While the subscriber is talking, relays 66 and 71, as in the circuit of Fig. 2, are operated to give him control of the transmitting circuit. If the operator wishes to call a subscriber, she signals the desired station by introducing signaling current through the line jack to operate relays 84 and 85. Operation of relay 84 removes relays 24 and 25 from the control of relay 63, while relay 85 is caused to pulse to operate relays 24 and 25 at the signaling frequency. As with the station circuit, the carrier wave is modulated at the signaling frequency and the modulated carrier wave is transmitted to the power line and to the station. When the operator connects a subscriber's station with another telephone system through conventional switchboard facilities through a cord circuit connected to the line jack, conversation between the outside party and the power line system party is accomplished in the same manner as is conversation between the latter party and the operator.

What is claimed is:

1. A power line carrier frequency telephone system comprising a subscriber's station coupled to the power line, means at said station for transmitting a high frequency electric wave to the power line, the transmitting means normally being disabled and including means for modulating waves of audio frequencies on the high frequency wave, and means to enable said transmitting means, said enabling means being coupled to said modulating means and operated by a portion of the output of said modulating means when voice energy is impressed on the transmitting means.

2. A power line carrier frequency telephone system comprising a subscriber's station coupled to the power line, said station comprising a high frequency transmitting circuit including a modulator, a source of high frequency waves to be modulated, means normally disabling said source, and means to be operated by output from the modulator when audio frequency waves are impressed on the modulator to counteract said disabling means whereby the high frequency wave is impressed on said modulator.

3. A power line carrier frequency telephone system comprising a subscriber's station coupled to said line, said station comprising a high frequency transmitting circuit including a transmitter to be acted upon by sound waves, a modulator to have impressed thereon low frequency currents corresponding to the sound waves, a source of high frequency waves connected to said modulator to be modulated in accordance with said low frequency currents, said high frequency wave source normally being prevented from supplying said high frequency wave to the modulator, and means to enable said source, said enabling means being operated by rectified low frequency current derived from said modulator.

4. An electric wave transmission system comprising a source of low frequency electric waves, a source of high frequency electric waves, a modulator in which the low frequency waves are modulated on the high frequency waves, means to prevent flow of the high frequency waves to said modulator, and means operating on a portion of the modulator output when low frequency waves are supplied to said modulator to counteract the effect of said first-mentioned means.

5. An electric wave transmission system comprising a source of low frequency electric waves. a source of high frequency electric waves, a modulator in which the low frequency waves are modulated on the high frequency waves, means to prevent flow of the high frequency waves to said modulator, and additional means operating when low frequency waves are supplied to said modulator, the output of said modulator containing a rectified component of said low frequency waves, said rectified component causing said additional means to disable said first-mentioned means to enable high frequency waves to flow to said modulator.

6. An electric wave transmission system comprising a source of low frequency electric waves, a source of high frequency electric waves, a modulator comprising a plurality of variable resistance devices arranged to include a direct current component in its modulation products when the low frequency waves are impressed thereon, means to prevent supply of high frequency waves from said high frequency source when no low frequency waves are being impressed on said modulator, and means operated by said direct current component when low frequency waves are impressed on the modulator to counteract the effect of said first-mentioned means.

7. A power line carrier frequency telephone system using a single carrier frequency wave for transmission in each direction comprising a subscriber's station coupled to the power line and including a transmitting circuit and a receiving circuit, said transmitting circuit normally being enabled, means to enable said transmitting circuit and simultaneously to disable said receiving circuit by short-circuiting the input to said receiving circuit, and means between the power line and said receiving circuit to provide a high impedance to the output of said transmitting circuit when the latter is in use.

8. A power line carrier frequency telephone system comprising a telephone station coupled to a power line, means at said station for transmitting and for receiving on a common carrier frequency, the transmitting means normally being disabled and the receiving means normally being enabled, means to enable the transmitting means and to disable the receiving means, and means to disable said enabling means when transmission is incoming to the receiving means, said last-mentioned means being operated by a demodulation component of the incoming transmission.

9. A power line carrier frequency telephone system comprising a telephone station coupled to a lower line, a transmitting circuit and a receiving circuit at said station for transmitting and for receiving on a common carrier frequency, said transmitting circuit including a modulator, means normally rendering said transmitting circuit ineffective for outgoing transmission, and means

operating on an output component of said modulator when voice energy currents are supplied to the latter to counteract said first-mentioned means, and said receiving circuit normally being adapted to receive incoming transmission and including a demodulator, and means operating on an output component of said demodulator when transmission is incoming to the receiving circuit to disable said second-mentioned means in the transmitting circuit.

10. A transmission system comprising a power line, a telephone station coupled to said line, said station comprising a circuit for transmitting on a high frequency electric wave and a circuit for receiving on a high frequency electric wave, said transmitting circuit normally being disabled and including a modulator, means operated by a direct current component of the output of said modulator to enable said transmitting circuit when voice frequency currents are impressed on said modulator, said receiving circuit normally being enabled but being disabled by operation of said transmitting circuit enabling means, and said receiving circuit including a demodulator, and means operated by a direct current component of the output of said demodulator to disable the transmitting circuit enabling means when transmission is incoming to said receiving circuit.

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