Dec. 2, 1941. H. R. MOORE 2,264,396

POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

Filed Oct. 22, 1940

FIG. 1

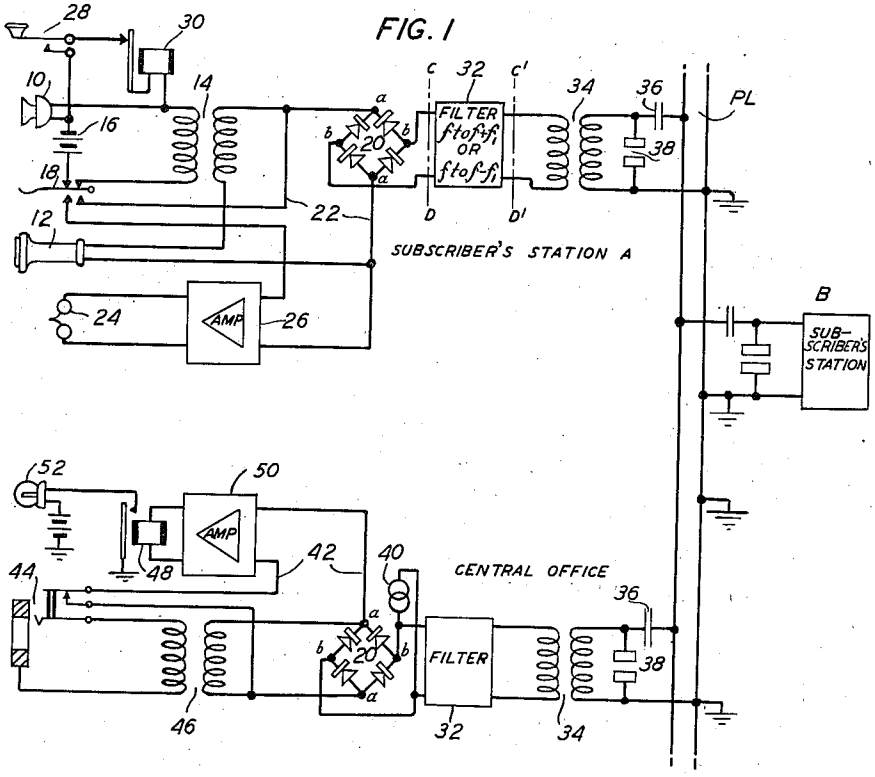


FIG. 2

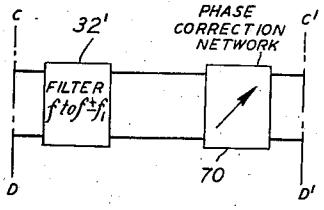
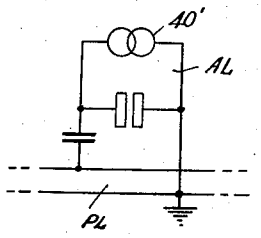


FIG. 1A



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POWER LINE CARRIER FREQUENCY TELEPHONE SYSTEM

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7 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.

Systems have been proposed heretofore to enable the transmission over power lines of telephonic communication utilizing one or more high frequency or carrier waves modulated in accordance with voice frequency waves. In such systems, however, the carrier frequency source or sources have been provided at each telephone station coupled to the power line, as well as at any central office or exchange for the system.

An object of this invention is to provide a power line telephone system in which a single carrier frequency source only is required.

When a carrier wave source common to the system is employed there is the possibility that there will be phase differences between the carrier wave at the calling station and at the called station.

Another object of the invention, therefore, is to minimize any adverse effects on telephonic communication that might result from such phase differences or phase shift.

A power line carrier frequency telephone system in accordance with the invention comprises a transmission line for transmitting electric power, for example, of high or low voltage and of relatively low frequency, between two or more points and to a plurality of power consumers some or all of whom, together with others in the locality through which the line extends, desire telephone service. Telephone subscribers' stations are coupled to the power line and are adapted to receive and to transmit telephone signals on high frequency or carrier waves. At each station and at the central office for the system, means are provided for modulating the carrier waves for transmission outgoing from the station or office, and for demodulating a modulated carrier wave incoming to the station or office. A single source of carrier wave common to the system is located at the central office, or at one of the stations, or may be coupled to the power line at some point along the line outside of a station or the central office. Because the distances between stations and between a station and the central office may be appreciable and will vary with the stations involved in a particular call, there may be phase differences between the carrier wave at the called or calling station and that of the calling or called station, that is, there may be phase differences in transmission occurring between the carrier wave employed for modulation and the carrier wave employed for demodulation. Any adverse effect, i. e., loss in demodulation output at the receiving station, that might follow from such a condition may be precluded by arranging the stations and the central office to transmit and to receive only the carrier wave and one side-band of the modulated carrier wave. In the event that it should be desired to transmit and to receive the carrier wave and both side-bands of the modulated carrier wave, each station and a central office (if the carrier wave source is not located thereat) are arranged to include phase correcting means.

A more complete understanding of this invention will be obtained from the detailed description which follows taken in conjunction with the appended drawing wherein:

Fig. 1 shows a power line carrier frequency telephone system incorporating the invention;

Fig. 1A shows an alternative location for the single source of carrier wave for the system of Fig. 1; and

Fig. 2 shows a circuit arrangement for inclusion in a modification of the circuit of Fig. 1.

The system shown in Fig. 1 is illustrative of the invention and comprises a plurality of telephone subscribers' stations A and B, coupled to a power line PL or other transmission media and a central office or exchange for the stations A, B, and such other stations as are coupled to the power line. As each telephone station will be the same, station A only is shown in detail.

The station A comprises a microphone or transmitter 10 which may be of the carbon granule type; a telephone receiver 12; an induction coil 14, one winding of which is adapted to be connected in series with the transmitter and a local battery 16, when the receiver has been removed from the switch hook 18, and another winding of which is adapted to be connected in series with the receiver across one pair of terminals *a*, *a* of a modulator-demodulator 20. It will be noted that regardless of the position of the switchhook the receiver circuit remains closed; normally, that is, when the subscriber at station A is not using his equipment, the receiver will be supported on the switchhook, and the battery circuit for the transmitter will be opened at the upper pair of switchhook contacts. Also connected across the modulator-demodulator terminals *a*, *a*, is a station signaling or ringing circuit 22 comprising a ringer 24 adapted to respond, for example, to a 20-cycle signal, which may be preceded by an amplifier 26, the ringing circuit normally being closed through the lower pair of switchhook contacts. A series circuit of a nor-

mally-open signaling key **28** and a circuit interrupter **30** adapted to interrupt the circuit, for example, twenty times a second when current is supplied to it, and to generate a 20-cycle per second signal in the receiver winding of the induction coil, is connected in parallel with the transmitter.

The modulator-demodulator may be of any suitable type, but it is preferred to employ a bridge arrangement of non-linear current-resistance characteristic devices, for example, copper oxide rectifier units. A wave frequency selective network or filter **32** is connected to the terminals *b*, *b* of the modulator-demodulator and to one winding of a transformer **34** provided to match the impedance of the subscriber's station to that of the power line. Of course, any other fixed or adjustable impedance matching device may be employed for the latter purpose. In accordance with one feature of the invention, the filter is designed to pass the carrier wave and either the upper or the lower side-band of the modulated carrier wave. That is, if the carrier wave frequency is denominated f and when modulated its side-bands are $f \pm f_1$, where f_1 would be the upper frequency, for example, 3500 cycles per second, of the voice frequency band to be transmitted and received at the stations in the system, the filter passes the band f through $f+f_1$ or the band f through $f-f_1$. The power line winding of transformer **34** is coupled to the power line through a condenser **36**, a suitable protector **38** being connected across the winding on the station side of the coupling condenser to preclude hazard to the subscriber or his equipment from high voltages arising in the power line. In the case of a single phase grounded neutral power line such as is shown only one coupling condenser is needed; with a fully insulated single phase power line, a coupling condenser in each line connection should be provided.

The central office circuit comprises a coupling condenser **36**, protector **38**, impedance matching transformer **34**, a band-pass filter **32** and a modulator-demodulator **20**, as in the case of a subscriber's station. A source **40**, however, of carrier wave, for example, any suitable constant frequency oscillator, is connected across the terminals *b*, *b* of the modulator-demodulator, and an operator's signal lamp circuit **42** is connected across its terminals *a*, *a*, the signal lamp circuit being completed through the operator's line jack **44** coupled through a transformer **46** to the terminals *a*, *a* of the modulator-demodulator. The operator at the central office would be provided, of course, with a suitable operator's telephone set (not shown) for talking and listening through the line jack. The signal lamp circuit comprises a relay **48** preceded by an amplifier **50** for operating at a low audio frequency, for example, 20 cycles per second, to close the signal lamp circuit when signaling current at that frequency is incoming to the central office from one of the subscribers' stations. Insertion of the operator's telephone set plug in the jack **46** opens the signal lamp circuit.

The operation of the system described is as follows: When a subscriber, for example, at station A wishes to call either the central office or another subscriber on the power line, he removes the receiver from the switchhook. This closes a circuit for the transmitter through the battery and induction coil winding, and connects battery to the interrupter. The calling party then closes and opens the interrupter circuit by use of the signaling key, the number of times required by the code employed in the system for calling a particular other subscriber or the central office. The low frequency alternating current (20 cycles per second) generated in the receiver winding of the induction coil is impressed on the modulator-demodulator acting as a modulator, and to which the carrier wave is continuously supplied from the carrier wave source at the central office. Among the products of modulation will be frequencies equal to the sum and difference of the carrier and the signal frequency. The carrier and the upper or lower side-band is passed by the filter to the power line.

At the called party's station, the incoming high frequency wave is demodulated by the modulator-demodulator acting as demodulator. If it is assumed that the called party's receiver is on its switchhook, the resulting low frequency signal is applied to the ringer through the ringing circuit amplifier. At the central office the low frequency relay is operated instead of a ringer, and closes the local battery circuit for the signal lamp. After the called party answers, or the operator responds—if she has been signaled, telephonic communication takes place, with the voice frequency currents modulated on the carrier wave at the talking station and the modulated carrier being demodulated at the listening station.

When the operator wishes to call a station on the power line, a low frequency (20 cycles per second) ringing voltage is applied through the line jack to the central office modulator-demodulator, known ringing arrangements associated with an operator's cord circuit being employed. The central office would be used primarily to connect a power line telephone system subscriber with a telephone subscriber in a general telephone system, an ordinary voice frequency transmission line being used to connect the power line system central office with that of the general telephone system.

In the system described, the source of carrier wave has been located at the central office. It may be located, however, at any convenient point in the system. For example, it could be coupled to the power line as indicated at AL in Fig. 1A, and be enclosed in a suitable pole-mounted or buried housing adjacent the power line. At both the central office and the subscriber's station, furthermore, the carrier frequency equipment could be mounted in a suitable housing adjacent the power line, connection from the carrier equipment to the station and central office voice frequency and signaling circuits being over voice frequency transmission lines.

It may be found desirable to transmit and to receive both side-bands of the modulated carrier. When this is the case, however, phase correcting means **70** (Fig. 2) is required at each subscriber's station (and at the central office if the carrier wave source is located at AL, and the filter **32** is replaced by a filter **32'** designed to pass the band f to $f \pm f_1$. The arrangement of Fig. 2 would replace filter **32** between CD—C'D' at each station, and a filter **32'** would replace the filter **32** at the central office. The phase corrector **70** adjusts for the phase differences in transmission that may occur between the carrier wave employed for modulation and the carrier wave employed for demodulation. Without phase correction, and depending on the length of transmission paths and the frequency of the carrier wave, the average of the phases of the two side-bands

may sometimes differ by an odd multiple of 90 degrees from the demodulation carrier wave, with the result that the two useful demodulation products would cancel. Only when the phase difference is zero degrees, or an even multiple of 90 degrees, would the full output be realized. On a party line system where communication is desired with other parties as well as with the central office, the phase corrector should be adjustable to correct to the different line lengths that may be involved in different calls. The adjustment might be in any desired steps to produce the necessary phase shifts.

What is claimed is:

1. A power line carrier frequency telephone system comprising a power line, carrier frequency telephone stations coupled to said line, means at each station for modulating a carrier wave, for demodulating a modulated carrier wave, and for selectively transmitting the carrier wave and its side-bands, a common source of carrier wave for all of said stations, and means at each station to correct for difference in phase between the carrier wave at the station where modulated and at the station where the modulated carrier wave is demodulated.

2. A power line carrier frequency telephone system comprising a power line, carrier frequency telephone stations coupled to said line, a central office for said stations coupled to said power line, means at each station and at said central office for modulating a carrier wave, for demodulating a modulated carrier wave, and for selectively transmitting the carrier wave and its side-bands, a common source of carrier wave for all of said stations and said central office, said carrier wave source being coupled to the modulating and demodulating means at the central office, and means at each of said stations only, to correct for difference in phase between the carrier wave at the station where modulated and at the station where the modulated carrier wave is demodulated.

3. A power line carrier frequency telephone system comprising a power line, carrier frequency telephone stations coupled to said line and adapted to communicate directly with each other over said power line on a single carrier wave for transmitting and receiving, said carrier wave being supplied to said stations from a common source located along said power line, and means at each station for modulating said carrier wave with voice and signaling frequency waves, for demodulating the modulated carrier wave, and for selectively transmitting and receiving said carrier and one side-band only of the modulated carrier wave.

4. A power line carrier frequency telephone system comprising a power line, carrier frequency telephone stations coupled to said line, a carrier frequency central office for said stations, said stations being adapted to communicate directly with one another and with the central office on a single carrier wave for transmitting and receiving, and a common source of carrier wave for said stations and said central office, each of said stations and said central office including means to transmit to and receive from said power line only the carrier wave and one side-band of the modulated carrier wave.

5. A power line carrier frequency telephone system comprising a power line, carrier frequency telephone stations coupled to said line, a carrier frequency central office for said stations, said stations being adapted to communicate directly with one another and with the central office on the same carrier wave for transmitting and receiving, and a common source of said carrier wave for said stations and said central office, each of said stations and central office including means to transmit and receive from said power line only a preassigned band of frequencies.

6. A power line carrier frequency telephone system comprising a power line, a plurality of carrier frequency telephone stations coupled to said line, a carrier frequency central office for said stations, each station and said central office including a combined modulator-demodulator having a pair of audio frequency terminals and a pair of carrier frequency terminals, an audio frequency receiving and transmitting circuit connected to said audio frequency terminals, a carrier frequency circuit connected between said carrier frequency terminals and said power line, said stations being adapted to communicate directly with one another and with the central office on the same carrier wave in transmitting from and receiving at said stations and central office, and a source of said carrier wave for connection in the carrier frequency circuit for continuously supplying the carrier wave to the stations and the central office of the system, each of said stations and central office including means in the carrier frequency circuit thereof to transmit to and to receive from said power line only a preassigned band of frequencies but including said carrier wave.

7. A power line carrier frequency telephone system comprising a power line, a plurality of telephone stations and a central office for said stations coupled to said line, a single carrier frequency source for continuously supplying a single carrier frequency electric wave to said line, stations and central office, all carrier frequency transmitting from and receiving at said stations and central office being on the same carrier frequency wave, and means at each station for directly signaling to and for carrying on a conversation with another station on the line and for signaling to and communicating with the central office, said means including a combined modulator-demodulator comprising a plurality of non-linear current-resistance characteristic devices, and a carrier frequency filter for transmitting only a preassigned band of frequencies including the carrier frequency wave to and from said combined modulator-demodulator.

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