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ELECTRIC WAVE TRANSMISSION SYSTEM

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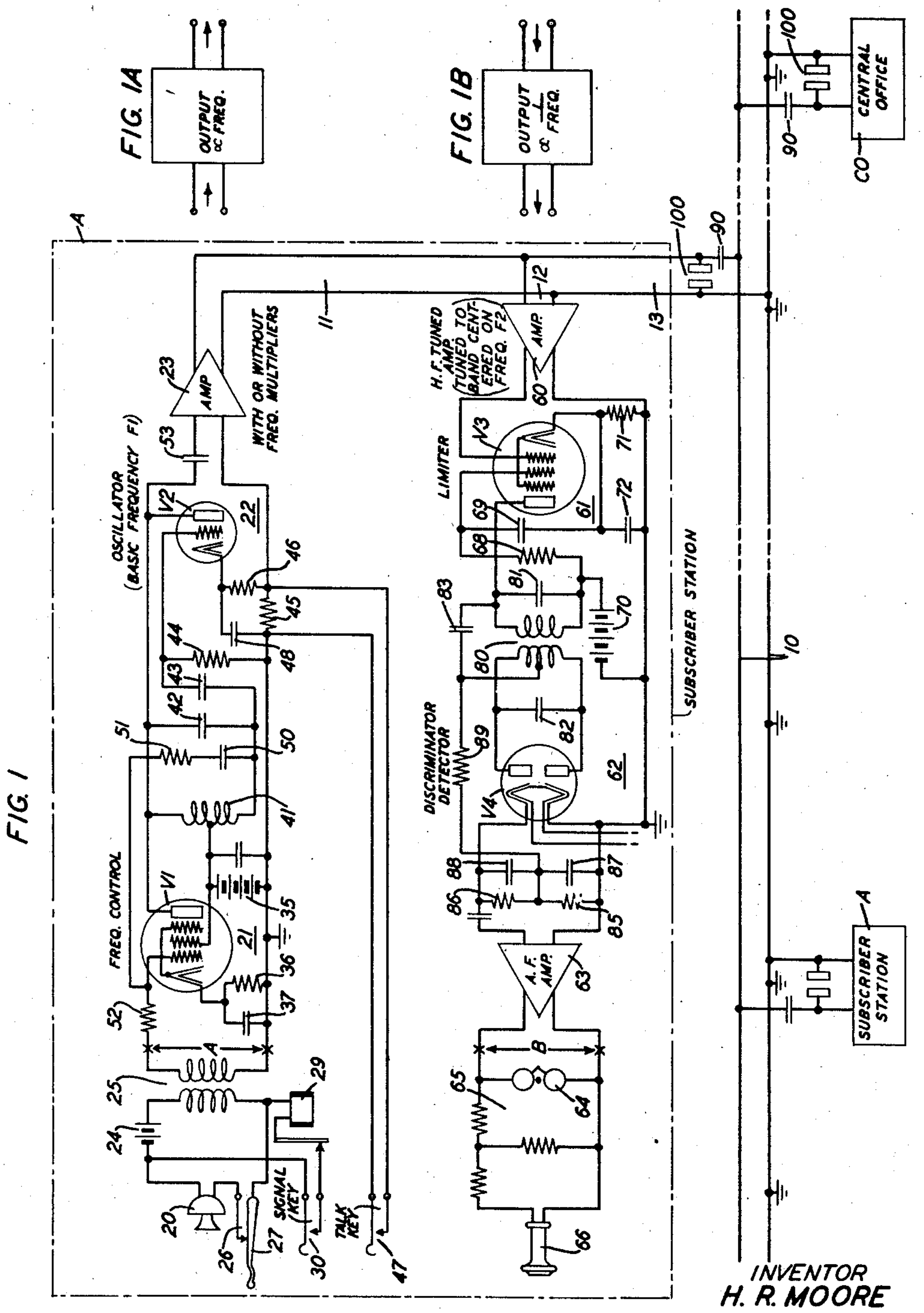

FIG. 1A

FIG. 1B

FIG. 1

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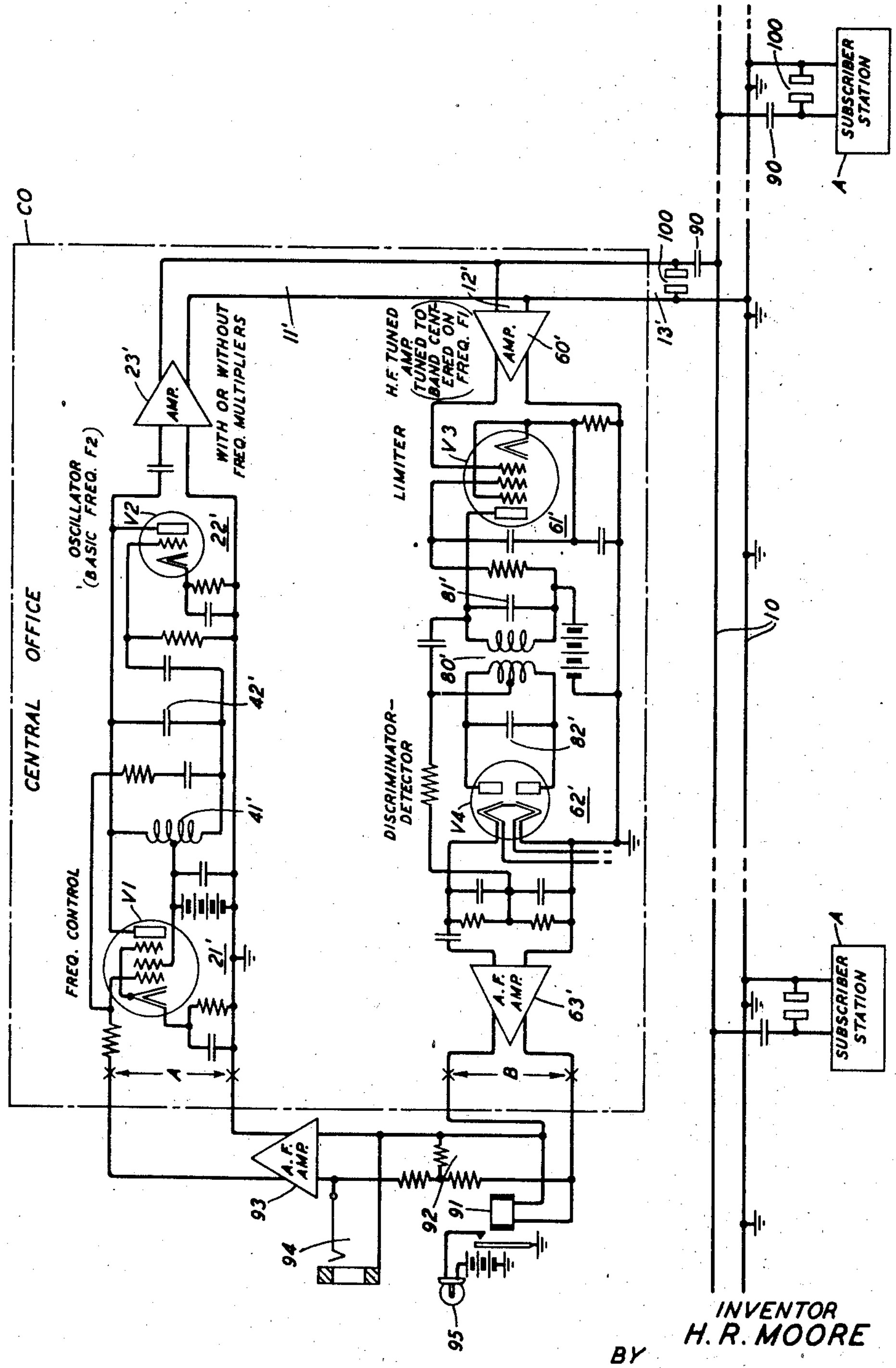
FIG. 2



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ELECTRIC WAVE TRANSMISSION SYSTEM

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4 Claims. (Cl. 179—2.5)

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

Carrier frequency telephony over transmission lines primarily intended for transmission and distribution of low frequency electric power is known. Such telephonic transmission has been by means of a carrier wave or waves amplitude modulated in accordance with the telephonic signal or voice frequency currents constituting the modulating current or wave.

An object of this invention is to improve carrier frequency telephony over power transmission lines.

There has been an increasing extension of rural power lines in recent years. These lines more frequently than not make use of single phase high voltage power distribution circuits in which one of the phase wires is insulated and the other is grounded at all distribution transformers and at numerous other points. Such lines offer the possibility of providing telephone service to the power consumers on the line in the usually sparsely settled regions through which the line extends, such telephone service being on high frequency or carrier waves.

Transmission losses, however, over such lines at the higher carrier frequencies are quite large and are marked by numerous irregularities. Practical coupling of the necessary carrier equipment for the telephone subscriber stations and the central office for the power line telephone system, usually involves further sizable losses, and still other losses are introduced by bridged power line taps and by connections from branch distribution lines. An ordinary amplitude modulated carrier frequency telephone system operating over such a facility involves fairly high transmission levels, sensitive receiving equipment, and, because of widely different losses over the various links of a party line arrangement, automatic gain control. Preservation of an adequate signal-to-noise ratio event with relatively high transmission levels appears to require use of carrier waves of a frequency above about 200 kilocycles inasmuch as the circuit noise increases rapidly below that frequency.

In contrast, a wide band frequency modulation system by reason of its inherent noise advantage, may be operated at considerably lower transmission levels, effecting a saving in equipment and operating costs. Alternatively, or, also, such a system could be operated at lower frequencies where the line attenuation would be less. Automatic volume control would also be inherent in such a system. Transmission distortion because of irregularities in the attenuation-frequency characteristic of the power line, important in the case of an amplitude modulation system, is of lesser concern in the case of a frequency modulated system.

A feature of the invention comprises transmitting and receiving over a power line on a high frequency or carrier wave angularly modulated in accordance with telephonic signal or voice frequency waves.

Another feature of the invention comprises a system and means for enabling carrier frequency telephony over a power line in which the carrier wave may either be frequency, phase or otherwise angularly modulated in accordance with the modulation current or wave.

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 transmit telephonic signals on high frequency or carrier waves. At each station, and at the central office for the system, means are provided for angularly modulating the carrier waves for transmission outgoing from the station or office, and for demodulating an angularly modulated carrier wave incoming to the station or office. In the particular system to be described in detail hereinafter, transmission from each station is on a common high frequency or carrier wave, and receiving at each station is on a second common high frequency or carrier wave, the central office for the system constituting a relay or frequency change-over station. Each telephone station embodies a separate source of the one carrier wave, and the single source of the second carrier wave is located at the central office and is continuously supplying the second carrier wave to the power line. The carrier frequency equipment at each station and the central office may be arranged for operation either on a frequency modulation or a phase modulation basis or both.

A more complete understanding of this invention will be derived from the detailed description that follows, read with reference to the appended drawings, wherein:

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

Figs. 1A and 1B show networks for insertion, under certain circumstances, at points A and B of Fig. 1 and of Fig. 2; and

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

Fig. 1 shows a portion of a power line carrier frequency telephone system comprising a power line **10**, a plurality of telephone subscriber stations A, one of which is shown in detail, and a central office CO for the system. Each station may communicate with the other stations in the system by way of the central office but without the interposition of the operator at the central office, and, also, with the operator when desired. The line is shown as a single phase power line with one conductor grounded at a multiplicity of points along its length; 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.

Each telephone station A comprises a transmitting circuit **11** and a receiving circuit **12** constituting branches of the line **13** coupling the station to the power line.

The transmitting circuit comprises a transmitter **20**, for example, of the granular carbon type, a frequency control circuit **21**, an oscillator **22**, and an output amplifier **23**. The transmitter is connected in series with a source **24** of talking current, one winding of a repeating coil or transformer **25**, and the telephone receiver switchhook contact set **26**. When the station is not in use, the telephone receiver is supported on the switchhook **27** and the contact set **26** would be open. A low frequency (for example, 20 cycles per second) interrupter **29** is connected in series with the normally open contact set **30** of a signal key, the source **24** and the primary winding of transformer **25**.

The frequency control circuit comprises the multigrid electron discharge device V1 having an indirectly heated cathode, an input control grid, a suppressor grid connected with the cathode, a screen grid and an anode. Anode potential and cathode-anode space current is supplied from source **35**, bias for the input grid being derived from the cathode resistor **36**, by-passed for alternating current by the condenser **37**.

The oscillator may comprise an electron discharge device V2 having an indirectly heated cathode, an input grid and an anode. The oscillatory network comprises a parallel-connected inductance **41** and capacitance **42** between the grid and anode of device V2, the anode of the oscillator being supplied with potential from source **35**. The condenser **43** isolates the oscillator's grid from the source of anode potential. Bias for the grid of device V2 is provided through resistance **44** by the cathode resistors **45**, **46**, and normally (that is, during a non-talking or non-signaling period) is of a value sufficient to prevent oscillation of the device. A normally open key **47** is connected across resistor **45**; when closed, it short-circuits the resistor **45** whereby the oscillator's grid bias is reduced sufficiently to permit the generation of sustained oscillation of high frequency, say, F1. Condenser **48** by-passes this high frequency way around the bias resistors.

The input grid of the device V1 is coupled to the oscillatory circuit through an anode-potential blocking condenser **50** and a resistance **51**, the latter having a value sizably greater than the reactance of the grid-cathode capacitance of the tube V1. As a result, the grid excitation of the multigrid device lags the voltage across the network of inductance **41** and capacitance **42** by approximately 90 degrees and so, also, does the cathode-anode current of the device. This lagging current, flowing through inductance **41**, changes the effective reactance of the oscillatory network, and, consequently, the frequency of the oscillation generated by the oscillator, the change or shift in frequency depending upon the change in the cathode-anode current of the tube V1. The normal space current for the latter may be varied by choice of the grid biasing resistor **36**, and, hence, within limits, the steady state frequency of the oscillator. Speech or signal currents impressed between the grid and cathode of the device V1 through the secondary winding of transformer **25** and resistance **52**, cause alteration of the grid potential and, consequently, of the cathode-anode current, effecting corresponding changes in the frequency of oscillation of the device V2 to values equally spaced above and below the steady state frequency F1 in accordance with the input signal to the tube V1. The resultant frequency modulated output is applied by way of the coupling condenser **53** to the amplifier **23**, which may be arranged for frequency multiplication, if desired, and through the line **13** to the power line.

The receiving circuit **12** of a station A comprises a high-frequency tuned amplifier **60**, an amplitude limiter circuit **61**, a discriminator-detector circuit **62**, an audio frequency amplifier **63**, a station signal or ringer **64**, an attenuation network or resistance pad **65**, and a telephone receiver **66**. This circuit is normally in condition for reception, i. e., the components thereof are continually energized.

The tuned amplifier may be of any conventional type known in the radio frequency art, and is designed to transmit an incoming angularly modulated high frequency or carrier wave F2 and its sidebands, but to reject the high frequency F1 and its sidebands, thus making the substation circuit anti-sidetone and precluding singing around the substation circuit. The second high frequency F2 will be sufficiently separated from the high frequency F1 used for transmitting from the station so that there is no overlapping of the sidebands of the two carrier waves when angularly modulated.

The limiter circuit comprises an electron discharge device or tube V3 of the multigrid type deriving its anode and its screen grid potential from a source **70**, and its input grid biasing potential from the cathode resistor **71**, by-passed for alternating current by condenser **72**. The anode or screen potential and the input grid bias for the device V3 are such that the tube overloads for amplitudes of the incoming wave above a preassigned normal level, thereby precluding further transmission of noise or other extraneous components of greater amplitude than the carrier wave. The screen grid potential is reduced to desired value by resistance **68**, which is by-passed by condenser **69**.

The discriminator-detector circuit is of a known type employed in commercial frequency modulation receivers. It comprises a double diode V4 the anodes of which are connected through a transformer **80** to the anode-cathode circuit of the tube V3. Each winding of the transformer **80** has a condenser **81**, **82** connected thereacross, tuning the transformer to the high frequency F2. In addition to the inductive coupling between the windings of the transformer, capacitative coupling is provided by condenser **83**, resulting in the application to the anodes of the tube V4 of a voltage equal to the vector sum of the primary voltage and one-half of the secondary voltage of transformer **80**, the primary voltage being in quadrature with the secondary voltage at the resonant frequency. At frequencies above the resonant frequency, the phase is shifted in one direction and at frequencies below resonance in the other direction, causing the resultant voltages applied to the diode anodes to become unequal, first one and then the other anode being at the higher potential.

The output circuit of the double diode comprises the equal load resistances **85**, **86**, each by-passed for the carrier wave by condensers **87**, **88**, the common terminal of the resistances **85**, **86** being connected through the resistance **89**, of high impedance to the carrier wave, to the mid-point of the secondary or diode winding of the transformer **80**. The rectified voltage developed across the resistances is normally equal and opposite, i. e., when the unmodulated carrier wave F2 is incoming to the diode. When the frequency modulated carrier wave is impressed on the double diode, the voltages developed across the resistances **85**, **86** will be different, the resultant varying voltage across the resistances corresponding to the variations of the modulation component, and, hence, of the original modulating wave.

The amplifier **63** amplifies the detected modulation component and, dependent on whether the modulation component is a station signaling wave or a speech currents wave, delivers the amplified wave to the station signal **64**, or the station telephone receiver **66**, through the attenuator **65**.

As already noted, each station A is coupled to the power line through a line **13**, one conductor of the latter being connected to the grounded wire of the power line, and the other being connected through a condenser **90** to the non-grounded wire of the power line. This condenser is suitably proportioned so that it offers a high impedance to the low frequency electric power but low impedance to the carrier waves. A suitable protector block **100** is connected between the conductors of the line **13**.

Before describing the operation of the station in originating and receiving a call to and from another party on the power line system or to and from the operator at the central office, the arrangement at the central office will be described.

Each subscriber station is arranged for transmitting on one high frequency wave F1 and for receiving on a second high frequency wave F2. The central office, as shown in Fig. 2, is arranged however, for transmitting on the second high frequency wave F2, and for receiving on the first high frequency wave F1. So far as the carrier wave equipment is concerned, the central office and the subscriber station A are the same, except that the steady state frequency developed by the oscillator **22'** in the transmitting circuit **11'** is that of the carrier wave F2, and in that the high frequency tuned amplifier **60'** is tuned to a band centered on the high frequency F1. The constants of inductance **41'** and capacitance **42'** are of appropriately different values, as are those of the coupling transformer **80'** and its associated tuning condensers **81'**, **82'**. The oscillator **22'** is normally continuously in oscillation, supplying the high frequency F2 to the line at all times. The output terminals of the audio frequency amplifier in the receiving circuit **12'** are connected to a low frequency (for example, 20 cycles per second) relay **91**, and through an attenuator or resistance pad **92** to the input terminals of an audio frequency amplifier **93**, for example, of the voice operated gain adjusting type, and to an operator's line jack **94**. The high frequency portion of the central office arrangement need not be housed within the office, but may be located at any convenient point, for example, in a housing adjacent to the power line used as the transmission path. In such a case, connection to the office would be over a voice frequency line interposed between the operator's jack **94** and the remainder of the equipment. Signaling could be relayed from the relay **91** to the signal lamp **95** over a simplex circuit consisting of the voice frequency line with ground return.

Let it be assumed that a subscriber at one station on the power line wishes to establish a connection with another subscriber at a second station on the power line. The circuit arrangement at the calling station would be that shown in Fig. 1. The calling party operates the key **47** to close its contact set, thereby short-circuiting resistor **45**, and reducing the bias on the control grid of the tube V2, whereby it generates the high frequency or carrier wave F1. The calling party then operates the signal key to close and to open the interrupter circuit in accordance with the calling code for the system. Each time the signal key is closed, the low frequency generated in the primary winding of the transformer **25** by the operation of the interrupter induces the signal wave in the secondary winding and across the grid-cathode circuit of the tube V1. The resultant changes in the anode current of the device V1 change the effective reactance of the oscillatory circuit of the oscillator, and vary the oscillator frequency in accordance with the signal wave. The high frequency wave F1, together with its sidebands, is amplified in amplifier **23** and transmitted to the power line **10**, and over it to the central office. Here the frequency modulated carrier wave is transmitted by the tuned high frequency amplifier **60'** to the amplitude limiter circuit **61'** and thence to the discriminator-detector circuit **62'** in which the signal wave modulation component is detected and transmitted to the audio frequency amplifier **63'**. The output of the amplifier operates the relay **91** causing the signal lamp **95** to operate. Simultaneously the amplifier output is applied to the amplifier **93**. The amplified audio frequency output is impressed on the frequency control circuit **21'**, and by causing variation in the effective reactance of the oscillatory circuit of oscillator **22'** frequency modulates the high frequency wave F2 generated by the oscillator **22'**. The high frequency wave F2 and its sidebands are amplified in the amplifier **23'**, and transmitted to the power line and over the latter to each of the other stations A coupled to the power line. Since the receiving circuit at each station is continuously energized, i. e., in condition to receive, the signal wave modulated high frequency wave F2 is transmitted by the tuned amplifier **60**, limited in amplitude in the amplitude limiter circuit **61** and demodulated in the discriminator-detector circuit **62**. The reconverted audio frequency signal wave is amplified in the amplifier

63, and transmitted to the signal device 64 to operate it. The device 64 operates each time and during the time the signal key at the calling station is closed. When the calling party ceases to signal, the party at the station whose code has been signaled, responds by removing his receiver from its hook, closing his normally open key 47, and beginning to talk. During conversation, each party transmits on the carrier wave F1 and receives on the carrier wave F2, the frequency modulated carrier wave transmitted from each station passing through the central office where it is demodulated and the demodulation component remodulated on the second high frequency wave that each station is adapted to receive. In each case, the carrier wave will be frequently modulated in accordance with the voice frequency currents in the transmitter circuit at each station when the party thereat talks into his transmitter 20 and generates such voice currents corresponding to the sound waves acting on the transmitter diaphragm. When the conversation is completed, each party restores his station to its normal or receiving condition by restoring the key 47 to its normally open condition by replacing his receiver 66 on its switchhook 27.

If the calling party desires to establish connection with the operator at the central office instead of with another subscriber on the power line, he operates his signal key (after closing the key 47) in accordance with the code for the central office. The operator responds by inserting the plug of the operator's set (not shown) in the line jack 94 and beginning the conversation. The operator transmits on the high frequency wave F2, and receives on the high frequency wave F1. The central office may be equipped with conventional facilities for connecting the subscriber with a general telephone system. When a call is incoming to the central office from the latter system, the operator signals the desired power system telephone station by operating her low frequency ringing key in accordance with the code for the power line system, the signaling taking place on the high frequency wave F2, frequency modulated in accordance with the low frequency signal wave.

Although the system described specifically hereinabove involves the use of a high frequency or carrier wave frequency modulated in accordance with the signal or the voice currents wave, the advantages of such a system may also be achieved by use of other methods of angular modulation, more particularly, phase modulation. The fundamental difference between a frequency and a phase modulated wave is that in the frequency modulated wave the frequency shift or deviation produced by the modulation is independent of the modulating frequency while in the phase modulated wave, the frequency deviation is directly proportional to the modulating frequency. It is apparent that the introduction of a suitable network in the audio input to the frequency control circuit of a frequency modulated transmitter will result in the production of a phase modulated wave. Such a network, indicated in Fig. 1A, having an output whose magnitude varies in direct proportion to the frequency of the input thereto, would be inserted at the points A in the station and central office transmitting circuits. Demodulation of the phase modulated wave may be accomplished with a circuit like that used for demodulation of frequency modulated waves, but, because the audio frequency output of such a demodulation circuit varies in direct proportion to the demodulated frequency, the network indicated in Fig. 1B should be inserted at points B in the station and central office receiving circuits. This network should have an output that varies in inverse proportion to the frequency of the input thereto.

In particular situations it may be desirable to utilize a modulation that is neither phase nor frequency modulation per se. In such an event, a network might be inserted at points A having an output that is independent of frequency at the lower modulating frequencies, but that increases in proportion to frequency at the higher modulating frequencies. A restoring network of complementary characteristics would be inserted at points B. More generally, any pair of predistorting and restoring networks having complementary output versus frequency characteristics might be employed, whether to achieve improved signal-to-noise ratios, or for any other purpose.

What is claimed is:

1. The combination of a power line for transmitting electric power, a plurality of telephone stations coupled to said power line, each of said stations adapted to transmit on a first high frequency electric wave and to receive on a second high frequency electric wave, means at each station to generate said first high frequency electric wave and to frequency modulate the electric wave in accordance with voice frequency currents corresponding to sound waves, means at each station tuned to a frequency band centered on said second high frequency electric wave and adapted to demodulate an incoming frequency modulated electric wave of said second frequency, a relay telephone station coupled to said power line, means at said relay station tuned to a frequency band centered on said first high frequency electric wave and adapted to demodulate a frequency modulated electric wave of said first frequency, and means at said relay station to generate said second high frequency electric wave and to frequency-modulate it in accordance with the demodulation components of the frequency modulated electric wave incoming to the relay station.

2. The combination as claimed in claim 1 in which the high frequency electric wave generated at said relay station is supplied continuously to the transmission line.

3. The combination of a line for transmitting electric power and means coupled to said line for telephonic communication over said line between separated points thereon, said means including a telephone station, said station comprising a transmitting circuit including an audio frequency transmitter, and a receiving circuit including an audio frequency telephone receiver; said transmitting circuit including an oscillator for generating high frequency electric waves, means under the control of the user of said station to set said oscillator to generating a single high frequency electric wave and to transmit it to said power line, means coupled to said audio frequency transmitter for modifying the output of said transmitter when audio frequency currents are generated in the latter and means responsive to said modified transmitter output for varying the frequency of said single high frequency electric wave; and said receiving circuit comprising a high frequency amplifier tuned to a frequency centered on a second high frequency electric wave, means for limiting the amplitude

of such a wave received in the receiving circuit from said power line, a detector circuit for translating the modulation component of such a band of high frequency waves into audio frequency electric waves for delivery to said telephone receiver, and an audio frequency electric wave distorting means in circuit between said detector circuit and the telephone receiver.

4. The combination of a line for transmitting electric power and means coupled to said line for telephonic communication over said line between separated points thereon, said means including a telephone station, said station comprising a transmitting circuit including an audio frequency transmitter, and a receiving circuit including an audio frequency telephone receiver; said transmitting circuit including an oscillator for generating high frequency electric waves, means under the control of the user of said station to set said oscillator to generating a single high frequency electric wave and to transmit it to said power line, a network coupled to said audio frequency transmitter and having a characteristic such that the magnitude of its output varies in direct proportion to the frequency of the input to the network from said transmitter, and means responsive to the output of said network for varying the frequency of said single high frequency electric wave; and said receiving circuit comprising a high frequency amplifier tuned to a frequency centered on a second high frequency electric wave, means for limiting the amplitude of such a wave received in the receiving circuit from said power line, a detector circuit for translating the modulation component of such a band of high frequency waves into audio frequency electric waves for delivery to said telephone receiver, and a network connected in circuit between said detector circuit and the telephone receiver, said network having a characteristic such that the output from said network varies in inverse proportion to the frequency of the input thereto.

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