

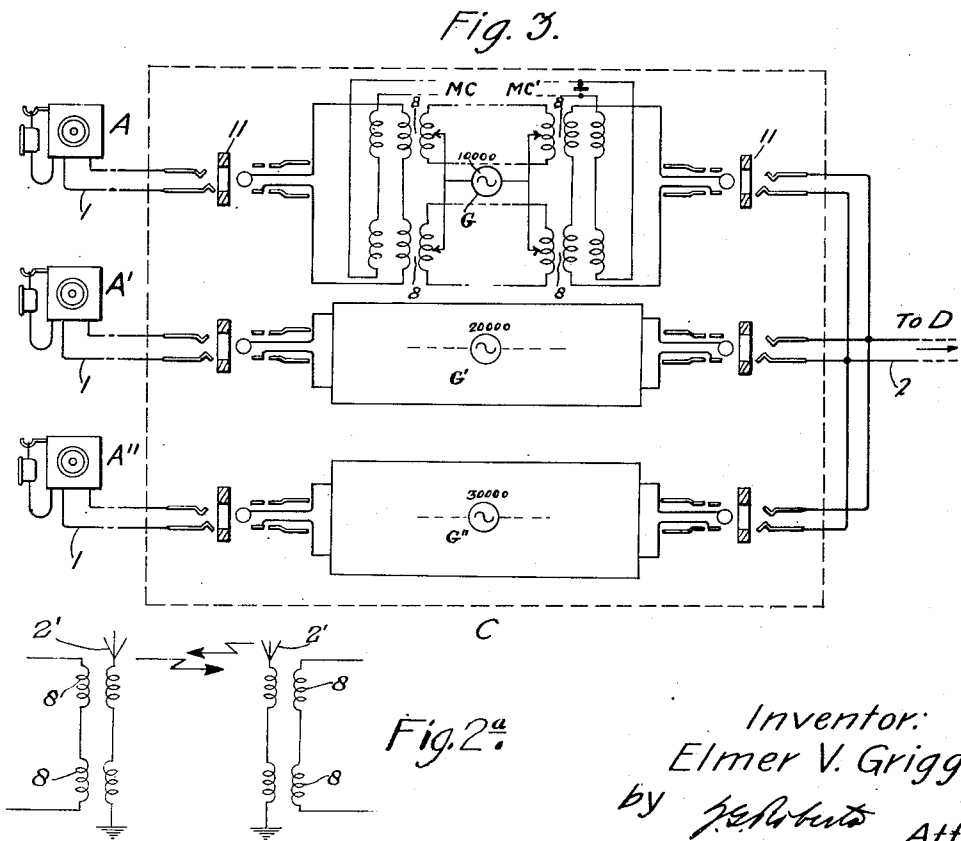
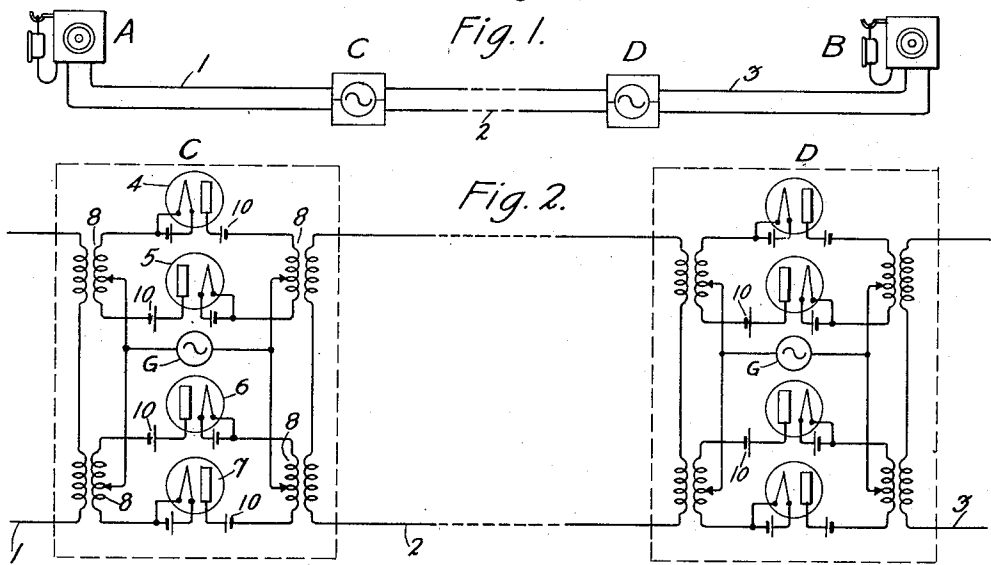
Nov. 3, 1925.

1,559,867

E. V. GRIGGS
WAVE TRANSMISSION SYSTEM

Filed Aug. 29, 1919

3 Sheets-Sheet 1



Inventor:
Elmer V. Griggs.
by *J. H. Roberts* Att'y.

Nov. 3, 1925.

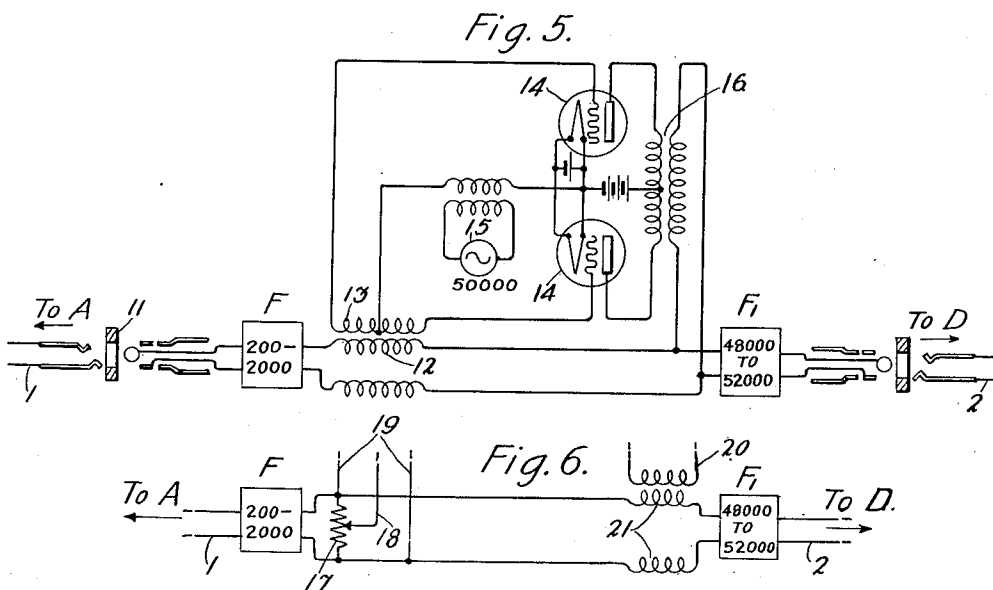
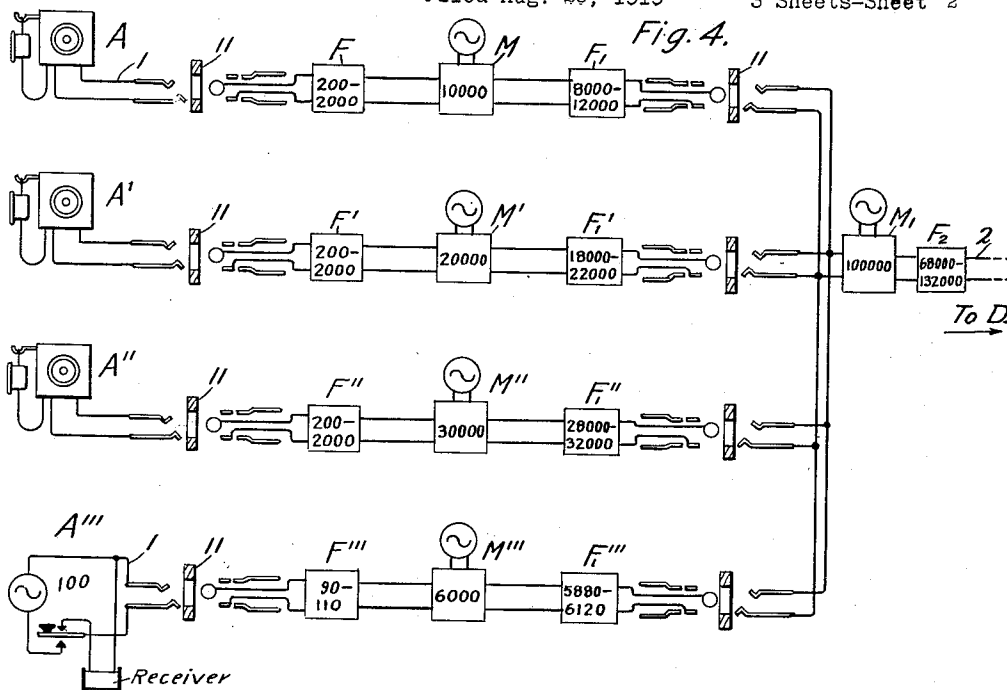
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3 Sheets-Sheet 2



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WAVE TRANSMISSION SYSTEM

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3 Sheets-Sheet 3

Fig. 7.

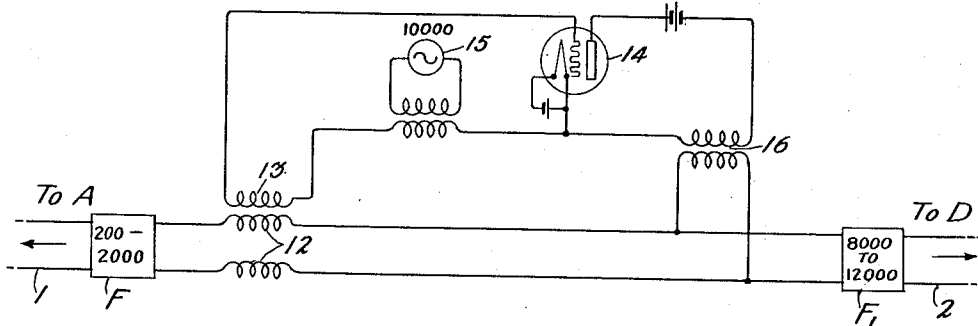


Fig. 8.

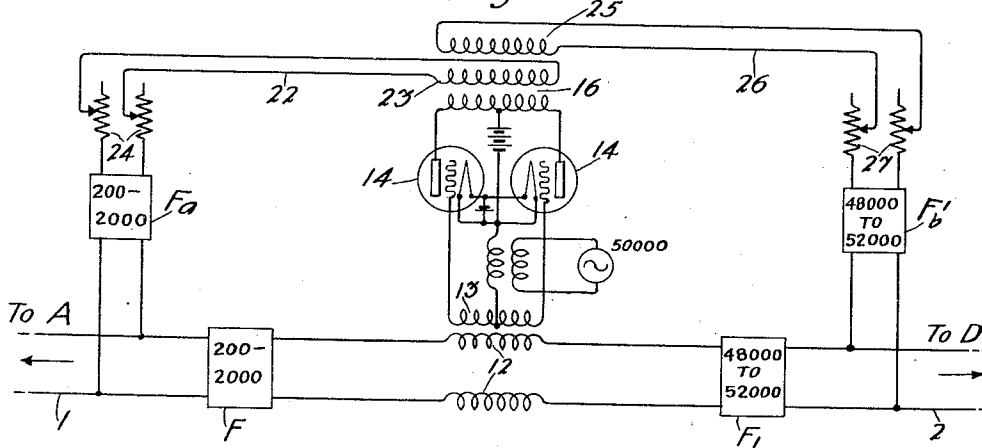
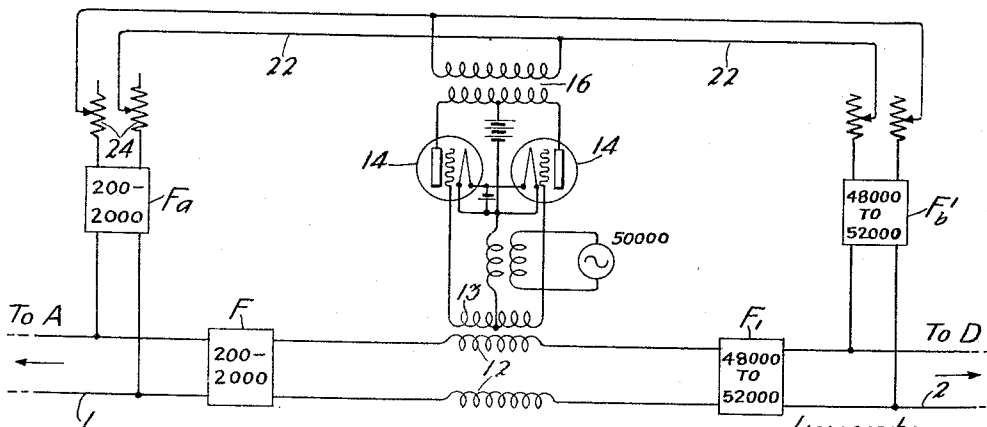


Fig. 9.



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UNITED STATES PATENT OFFICE.

ELMER V. GRIGGS, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

WAVE-TRANSMISSION SYSTEM.

Application filed August 29, 1919. Serial No. 320,553.

To all whom it may concern:

Be it known that I, ELMER V. GRIGGS, a citizen of the United States, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Wave-Transmission Systems, of which the following is a full, clear, concise, and exact description.

This invention relates to transmission systems and methods of transmission and more particularly to systems and methods for the transmission of signals by the use of carrier waves. In systems of this type, the energy of low frequency or signaling current is utilized to modulate the energy of higher frequency or carrier currents which are transmitted to a remote station and there detected by means of a detecting device which reproduces currents having a wave form or other characteristic or characteristics so related to the original signaling wave as to be available for the reproduction of the signal. In accordance with the invention a single device is provided for modulating outgoing and detecting incoming carrier waves in systems of this type.

One object of the invention viewed broadly may be stated to be the provision of a duplex system wherein reversible and interchangeable devices, having symmetrical conductivity, are provided for transferring in each direction the energy to be transmitted.

Another object is the provision of suitable forms of devices which may be connected in such a system to act either as a modulator or as a detector according to whether the energy is being transmitted or received.

Another object is to provide reversible and interchangeable devices which, when connected at any point in a signaling system by suitable transformers or equivalent means, will serve as a modulator for waves passing in one direction and as a detector for waves passing in the other direction irrespective as to which terminal of the device is connected to the low frequency side of the line.

In systems containing thermionic amplifiers, modulators or detectors, imperfect operation sometimes results from "singing" or the generation of undesired oscillations in some part of the system. Means are here

provided to eliminate or reduce this trouble.

Since an important advantage of carrier current systems over ordinary transmission systems is the facility with which they lend themselves to multiplex communication, several arrangements for multiplexing are herein shown and constitute an important part of the invention. Plural or successive modulation systems utilizing various novel features of the invention are also described herein.

A further object is that of providing novel forms of cord circuits whereby multiplexing may be facilitated and particularly whereby subscribers' lines may be conveniently and interchangeably connected to trunk lines. The modulator-detectors herein described are under certain circumstances, included in the cord circuits.

Another object is to provide reversible thermionic repeating systems requiring no space current sources, other than the waves to be transmitted and suitable carrier frequency generators.

Among the important advantages, peculiar to signaling, of systems utilizing the principles hereinafter described is that of reducing the necessity for balancing line impedances and the necessity for the provision of conjugate arrangements of incoming and outgoing low and high frequency circuits with respect to each other.

In general, the principles of the invention will be described herein mainly with reference to telephone systems, since telephony is the more comprehensive form of signaling, the principles of which apply to telegraphy and other less specialized forms of transmission in which the reproduction of a definite wave form is not essential. As used herein the word "line" will be understood to include any long or short conductive circuit either loaded or unloaded which may be adapted for the requirements of a particular installation. Certain features of the invention are of general application as, for example, to radio transmission and other electrical systems as well as to signaling over conductive circuits and hence will be claimed broadly. In particular, the fundamental idea of using a single apparatus to modulate outgoing and detect incoming waves is adapted for radio communication. For this purpose a pair of radiating con-

ductors, one at each station C and D, may be substituted for the line 2.

The invention will be more fully described in connection with the accompanying drawings wherein Fig. 1 is a diagrammatic representation of the essential features of a duplex system in accordance with the invention; Fig. 2 a more detailed diagram of the modulator-detector stations C and D of Fig. 1; Fig. 2^a shows a pair of antennae which may be substituted for the high frequency line; Fig. 3 shows an arrangement for multiplex signaling; Fig. 4 a modified form for plural modulation multiplex signaling; Fig. 5 a modified form of modulator-detector circuit; Fig. 6 a slight modification of the circuit arrangement of Fig. 5; Figs. 7, 8 and 9 are other modified forms of modulator-detector circuits.

Referring to Fig. 1, A and B are subscribers' substations which typify any two points between which telephonic communication is to be established. Voice currents of speech frequency, hereinafter called signaling currents, will be produced at station A and transmitted over a local line 1 to station C, where modulated electrical waves or currents are produced and transmitted over a high frequency line 2 to the station D and there detected to produce electrical waves similar to those produced at the station A which are transmitted over the local line 3 to the station B for the reproduction of the original signals. The apparatus at stations C and D are duplicates as may be seen by reference to Fig. 2 where they are shown in greater detail.

Referring to Fig. 2, apparatus C only will be described at length from which description the duplicate apparatus D will be readily understood. The apparatus C is herein styled a modulator-detector and consists of a carrier frequency generator G symmetrically connected through the coils 8 to the two pairs of uni-directionally conducting two electrode thermionic discharge tubes 4, 5, 6 and 7. Each tube preferably comprises a suitable highly evacuated containing envelope, a heated filamentary cathode and an anode. Normally the generator G will not cause any high frequency currents to be transmitted either to the line 2 or the line 1 owing to the balanced relation of the coils 8 with respect to the tubes, the lines, and the generator G, the latter being connected to the electrical midpoint of each coil. When, however, a current flowing in the line 1 causes an electromotive force to be induced in the coils 8 in a particular direction, the resulting unbalance of the current through the coils 8 will cause a modulated high frequency current to be impressed upon the line 2. In accordance with known principles, current in the line 2 will consist of what has previously been

described as a "pure modulated wave", that is, if the signaling frequency be a sinusoidal wave of frequency s and the frequency of the generator G be designated by p , where p is likewise a sinusoidal wave the current in the line 2 will consist of the sum of the superimposed currents whose frequencies are $p+s$ and $p-s$. Where s represents speech currents it may be taken as typical of the various sinusoidal waves into which the speech current at a given instant may be resolved.

The pure modulated wave will be transmitted to the station D and the frequencies $p+s$ and $p-s$ will there be combined with a wave of frequency p locally generated by the generator G which will result in a detected current being transmitted to the line 3 which current will, as one component thereof, include a current or wave of the frequency s . This current upon traversing the line 3 will be received at the station D to affect a receiving instrument in the usual manner to reproduce the sound of the original signal. Space current sources 10 may be included in the circuits of the tubes comprising the apparatus C. The sources 10 of each pair of tubes 4 and 5 are oppositely directed with respect to generator G. The sources 10 are not essential to render the system operative and may be considered to be of zero terminal voltage and negligible resistance. Preferably, however, the sources 10 are of substantial and equal voltage and produce a normal space current through the tubes when no signals are passing. The apparatus C and the apparatus D are interchangeable, symmetrical, reversible, and doubly functioning in that they will modulate currents to be transmitted and detect received modulated currents and reproduce therefrom the original signal, provided the generators G have the same or substantially the same frequency. The transformers of which the coils 8 form a part may have any winding ratios which will be desirable in particular instances. Repeating apparatus of this type which will pass energy in either direction constitutes an important feature of the invention. Fig. 2^a illustrates how antennae 2' may be substituted for the conductive line 2. Each antenna will be connected to its respective station C or D. The windings of the transformers 8 which are included in the line in Fig. 2 will be included in the antennae 2'. In this manner any of the arrangements herein described may be used for radio signaling by substituting wave radiating and absorbing antenna systems for the high frequency line.

Fig. 3 illustrates one manner of using the devices of Fig. 2 for multiplex transmission over the high frequency or trunk line 2. The apparatus shown corresponds to the stations A and C. Duplicate apparatus will be

provided at the stations D and B which are located at the remote terminus of the line 2. Line 2 is typical of any desired number of trunk lines which may terminate at distant stations similar to station D. Several circuits, such as shown at station C (Fig. 2) are included in the respective cord circuits at station C (Fig. 3). The cord circuits each include all the apparatus connected therein between the connecting jacks 11. The generators G in the cord circuits will each produce a different frequency. In the present instance the frequencies are 10,000, 20,000, 30,000 respectively, the word "frequencies" being used throughout this specification to indicate the number of cycles per second.

Now suppose a subscriber at one of the stations A, A' or A'' desires to communicate with a subscriber B. Upon calling the operator at C by any suitable calling or signaling means and advising her of his desire, the operator at C selects an idle cord circuit at that station and notifies the operator at D to call the particular subscriber B and connect him to the trunk line 2 by means of a cord circuit at the station B having a generator G of the particular carrier frequency which the operator at C desires to use. The cord circuit having the generator G'' with a frequency of 30,000 may be supposed to be selected and the subscriber A, A' or A'' as the case may be, is connected to the line D through that circuit. When subscriber A talks, the speech waves transmitted over the line 1 cause pure modulated waves to be transmitted over the line 2 to the station B where they are detected and thence are received by the subscriber B to reproduce the sounds of the voice of the subscriber A. Conversely the subscriber B can talk with the subscriber A in a similar manner through the same circuits and energy-transferring devices. Monitoring at the stations C and D may be done by a monitoring circuit MC connected to the low frequency side of the line. If, however, the operator's monitoring circuit contains a detector, the monitoring may be accomplished by connecting the monitoring circuit MC' to the high frequency side of the line. While as many cord circuits are illustrated as there are lines 1, a great many local lines 1 may be served by a comparatively few cord circuits.

Fig. 4 represents an arrangement adapted for the transmission of plurally modulated waves. A, A' and A'' are subscribers' stations and A''' a telegraphic station. The cord circuits preferably terminate in plugs adapted for connection to jacks 11 and contain filters F, F', F'' and F''' which are adapted to transmit the respective bands of frequencies indicated thereon. M, M', M'' and M''' are circuits such as shown at C

(Fig. 2), or their equivalents, having generators producing the carrier frequencies indicated thereon. F₁, F₁', F₁'', F₁''' are also band filters adapted to transmit the bands of frequencies respectively indicated thereon. M₁ is a circuit such as shown at C (Fig. 2) having its generator-frequency indicated thereon and F₂ is a band filter adapted to pass the band of frequencies from 68,000 to 132,000 as indicated.

The transmission of speech signals through a single one of the cord circuits in each direction will serve to explain the operation of this arrangement. For the purpose of this specification, it will be assumed that transmission of the band of frequencies from 200 to 2,000 will enable reproduction of speech of a sufficiently good quality and that higher and lower frequencies may be eliminated. Suppose the subscriber A is connected to the cord circuit containing the modulator M, then speech currents produced in the line 1 connected to the sub-station A will be transmitted through the filter F to the modulator M which will cause the transmission of a correspondingly pure modulated wave through the filter F₁ to the modulator M₁ which includes a generator constantly producing the carrier frequency 100,000 as indicated. From the modulator M₁ there will be transmitted through the filter F₂ to the line 2, a pure modulated wave having the base frequency 100,000 and modulated in accordance with the wave which passes the filter F₁. For incoming signals, the process is reversed and the devices M and M₁ will act as detectors whereby speech from the station B will be reproduced at the station A. If it is desirable to eliminate one of the side frequencies by the filter F₁ it may be designed to pass the range of frequencies from 8,000 to 10,000 or from 10,000 to 12,000 according to whether the upper or lower side-frequency band is to be eliminated. Telegraphy may be simultaneously carried on from or to one or more stations A'''. When considered in connection with the symbols on the drawings, the operations of transmitting and receiving telegraphic signals will be clear without further description. The carrier frequencies which are herein suggested are illustrative only and other suitable values may be selected. Likewise the various filters may be designed to pass such ranges of frequencies and to exclude such frequencies as may be found most desirable in practice. Other modulators such as M₁ may be connected to the line 2, each modulator M₁ being provided with a different carrier frequency and being connected to the line through a suitable filter, while at a remote point on line 2 similar communicating stations having the same carrier frequency are provided.

Figs. 5 to 9 inclusive represent forms of

modulator-detector circuits which may, if desired, be substituted for that shown at C (Fig. 2). Referring particularly to Fig. 5, the low frequency line 1 may be connected with or without the interposition of a jack or connecting means 11 to a speech-frequency filter F. The transformer 12 has one or more primary coils 12 coupled to the secondary coil 13. The terminals of coil 13 are connected to the respective grids of three-element thermionic repeaters 14 while the mid-point of the primary 13 is connected to the filaments of the repeaters. Included in the conductor connecting the mid-point of the secondary 13 is a suitable transformer or equivalent means upon which a suitable carrier frequency, as for example, 50,000 cycles is impressed by the device 15. The output circuits of the repeaters 14 are oppositely connected to the primary of a transformer 16 whose secondary has its terminals connected across the line. The filter F_1 is included in the line, the opposite terminal of this filter being adjacent the line 2. The terminal element of filter F comprises a low impedance path for high frequency currents passing through the primaries 12. This arrangement serves to modulate low frequency currents which are generated in the line 1 or to detect high frequency modulated currents whose base frequency is 50,000 which are received through the line 2. This apparatus may be substituted for one of the cord circuits shown in Figs. 3 or 4 and the operation will be analogous to the operation of the devices of those cord circuits as heretofore given.

In Fig. 6 a resistance or impedance 17 is shunted across the line and from mid-point of this resistance a conductor 18 extends which may be connected to the filamentary cathodes of a pair of repeaters, such as shown in Fig. 5. Other conductors 19 may be connected to the impedance-controlling elements of the repeaters. The secondary of the transformer 16 will, in this case, be included in circuit with a primary 20 of a transformer whose secondary 21 may consist of one or more coils serially included in the line in a manner similar to the coils 12 (Fig. 5). The arrangement of Fig. 6 will likewise receive low frequency currents from the line 1 and transmit modulated waves from which the unmodulated component of carrier frequency has been eliminated, to the line 2, the reverse action taking place in a case where the modulated waves are received from the line 2.

The arrangement shown in Fig. 7 differs from that of Fig. 5 in having a single repeater 14 instead of a duplex repeating arrangement comprising a pair of repeaters 14. With a single tube or repeater, no provision is made for eliminating the carrier frequency component from the outgoing

modulated current. If it is desired not to transmit the carrier frequency component the filter F_1 may be designed to pass only the range of frequencies $p+s$ or $p-s$, in each case eliminating p . For example, the transmitted band might be either 10,200 to 12,000 or 8,000 to 9,800 where the carrier frequency, p , is 10,000. Coil 13 is coupled to coils 12. Coil 13 is included in the input circuit of tube 14. The generator 15 typifies any convenient source of voltage of a suitable carrier frequency, for example, 10,000 cycles. The modulated current in the output circuit is impressed upon the line 2 through the transformer 16 and the filter F_1 . Incoming current is detected in a similar manner, the low frequency component being impressed upon the line 1 through transformer 16 and the filter F. The band filters F and F_1 pass only the range of frequency indicated.

Fig. 8 represents a further modified form of the arrangement of Fig. 5. The circuit 22 is connected to one secondary 23 of transformer 16 and feeds detected signaling frequency energy to the line 1 through the filter F_2 . The feed back connection of the circuit 22 is on the side of the filter F which is connected to the line 1. An attenuation device here illustrated as a resistance 24 may be provided to reduce the amount of energy fed back in case singing is troublesome. The high frequency modulated energy is similarly fed to the line 2 through circuit 26 which includes the secondary 25, the filter F_2' and the attenuating resistance 27. The terminal elements of filters F and F_1 are paths of low impedance for currents of the frequencies passed by filters F_1 and F respectively.

The arrangement illustrated in Fig. 9 differs from that of Fig. 8 only in that a secondary of the transformer 16 is connected to a divided circuit 22 for transferring both signaling and carrier current energy.

The thermionic detectors, modulators and repeaters herein shown will ordinarily act as energy amplifiers and in general may be regarded as performing this function.

The novel features inherent in the invention are pointed out in the accompanying claims.

What is claimed is:

1. The method of duplex carrier wave telephony which comprises producing speech currents at each end of a system, passing incoming and outgoing speech conveying waves through identical conductive paths but in opposite directions throughout the entire system, and changing the frequency of transmitted waves during transmission.

2. A two-way low frequency line, a two-way high frequency line, means for interconnecting said lines comprising a tele-

phone operator's cord circuit having a source of carrier frequency oscillations serially included between the terminals thereof.

3. A telephone cord circuit for use in carrier current systems serially including a frequency selective device, a source of carrier current, and a second frequency selective device, in the order named.

4. A two-way low frequency line, a two-way high frequency line, means for interconnecting said lines comprising a telephone cord circuit serially including a modulator of carrier waves.

5. A two-way low frequency line, a two-way high frequency line, means for interconnecting said lines comprising a telephone cord circuit serially including a detector for detecting carrier waves.

6. A two-way low frequency line, a two-way high frequency line, means for interconnecting said lines comprising a telephone cord circuit including a two-way conducting device constituting a modulator-detector.

7. A cord circuit containing two filters for transmitting different ranges of frequencies and a thermionic device included therebetween.

8. A cord circuit containing two band filters and a wave distorting device included therebetween.

9. A circuit for signaling comprising a band filter for passing a high range of frequencies, a band filter for passing a low range of frequencies, and a symmetrically conducting frequency-changing device connected between said filters.

10. A signaling system comprising a plurality of signal frequency channels, a plurality of connecting circuits each of which is adapted to be connected to any selected one of said channels, two-way conducting modulating-detecting means in each said circuit, and a two-way low frequency line and a two-way high frequency line adapted to be interconnected by said connecting circuits.

11. A duplex signaling system comprising two stations and a bidirectionally conducting modulator-detector device connected therebetween, said device serving as a modulator for signals passing in one direction and a detector for signals passing in the other direction.

12. A system comprising a source of alternating current, a plurality of pairs of thermionic devices connected to said source, the devices of each pair being oppositely poled with respect to said source, and another source of current with respect to which the devices of each pair are similarly poled.

13. A circuit for use in transmission systems, comprising a band filter for passing a range of frequencies, a second band filter for passing a different range of frequencies,

and a source of carrier frequency oscillations connected between said filters, said circuit comprising means for the transfer of energy in each direction therethrough.

14. A wave transfer circuit, comprising an input circuit and an output circuit and a pair of separate asymmetrically conducting circuits oppositely connected with respect to both the input and output circuits, each of said last mentioned circuits including a plurality of space discharge paths.

15. A wave transfer circuit, comprising a pair of input impedance elements, an incoming line including a source of waves to be transferred into said elements, and a local source of alternating current, each of said input impedance elements being divided into two parts, and said local source being oppositely connected to the two parts of each thereof.

16. A system comprising a plurality of pairs of thermionic devices, a source of alternating current, and a second source of alternating current, said pairs of devices being oppositely poled with respect to one of said sources and the individual devices of a pair being oppositely poled with respect to another of said sources.

17. A modulating system comprising a source of high frequency oscillations, a source of modulating oscillations, and an output path combined with a plurality of two-electrode thermionic devices connected to said sources by means whereby pure modulated oscillations are transferred to said output path and by means whereby the halves of the waves from said source of high frequency oscillations are symmetrically transferred.

18. A cord circuit for connecting two transmission circuits, said cord circuit containing two filters for excluding different ranges of frequencies, and a thermionic device included in said circuit between said filters.

19. A telephone exchange system comprising a plurality of cord circuits each provided with selective means, one of said selective means being adapted to pass a different range of frequencies than others thereof, two-way low frequency line and a two-way high frequency line are adapted to be interconnected by any one of said circuits.

20. A telephone exchange system comprising a plurality of cord circuits each provided with a source of carrier waves serially included therein, at least one of said sources having a different frequency than others thereof, and at least one two-way high frequency line which may be connected for two-way communication by any one of said circuits to any telephone line terminating in said exchange.

21. In a carrier wave system a source of low frequency waves, means including a

modulating device for stepping up the frequency of said waves to a higher frequency, other means including a second modulating device for stepping up the frequency of said waves of higher frequency to a still higher frequency, means for transmitting waves of said highest frequency, said transmitting means comprising means for receiving incoming waves, said second mentioned modulating means comprising means for reducing the frequency of the received waves, and said first mentioned modulating means comprising means for further reducing the frequency of said waves of reduced frequency.

In witness whereof, I hereunto subscribe my name this 26th day of August, A. D., 1919.

ELMER V. GRIGGS.