

July 11, 1933.

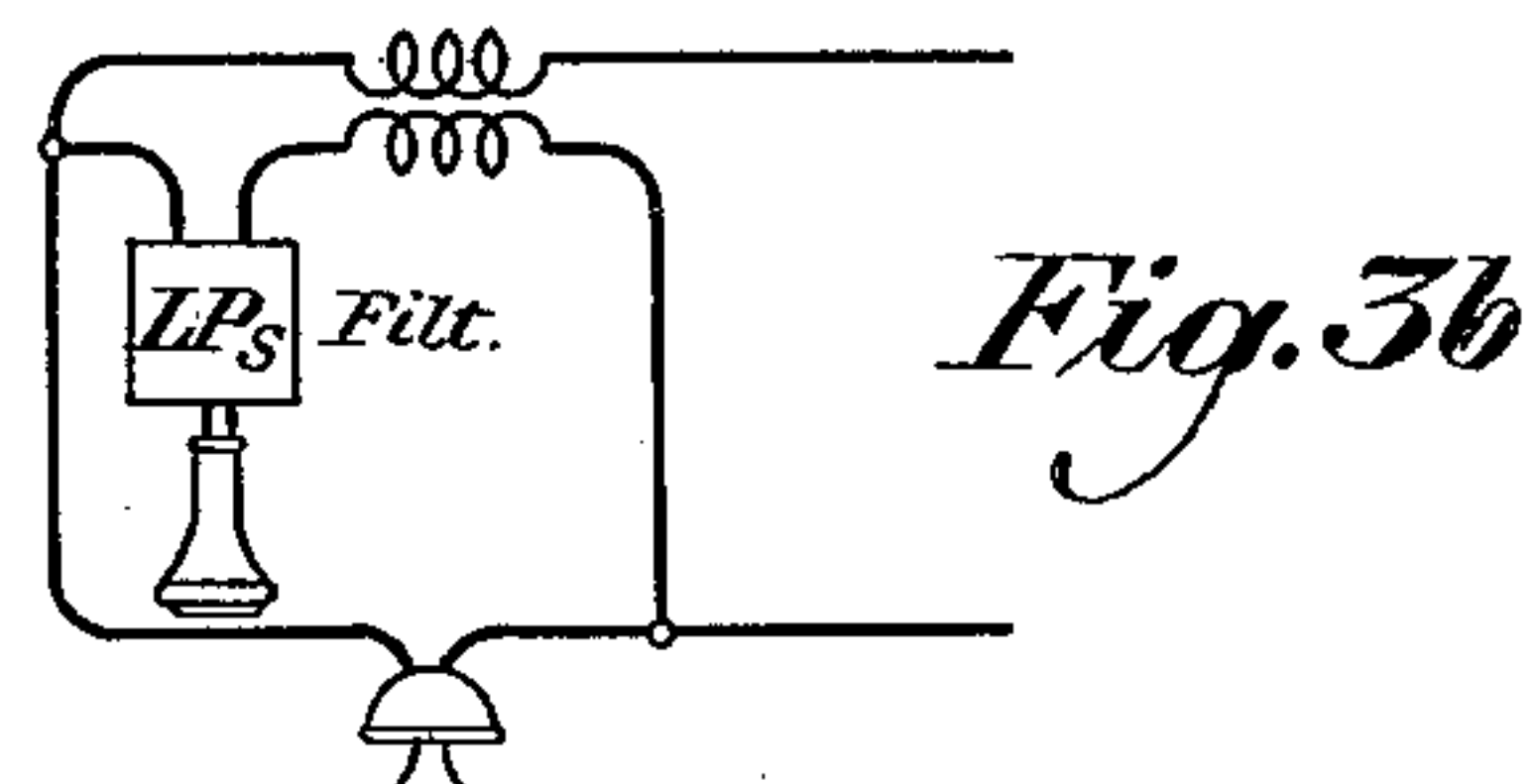
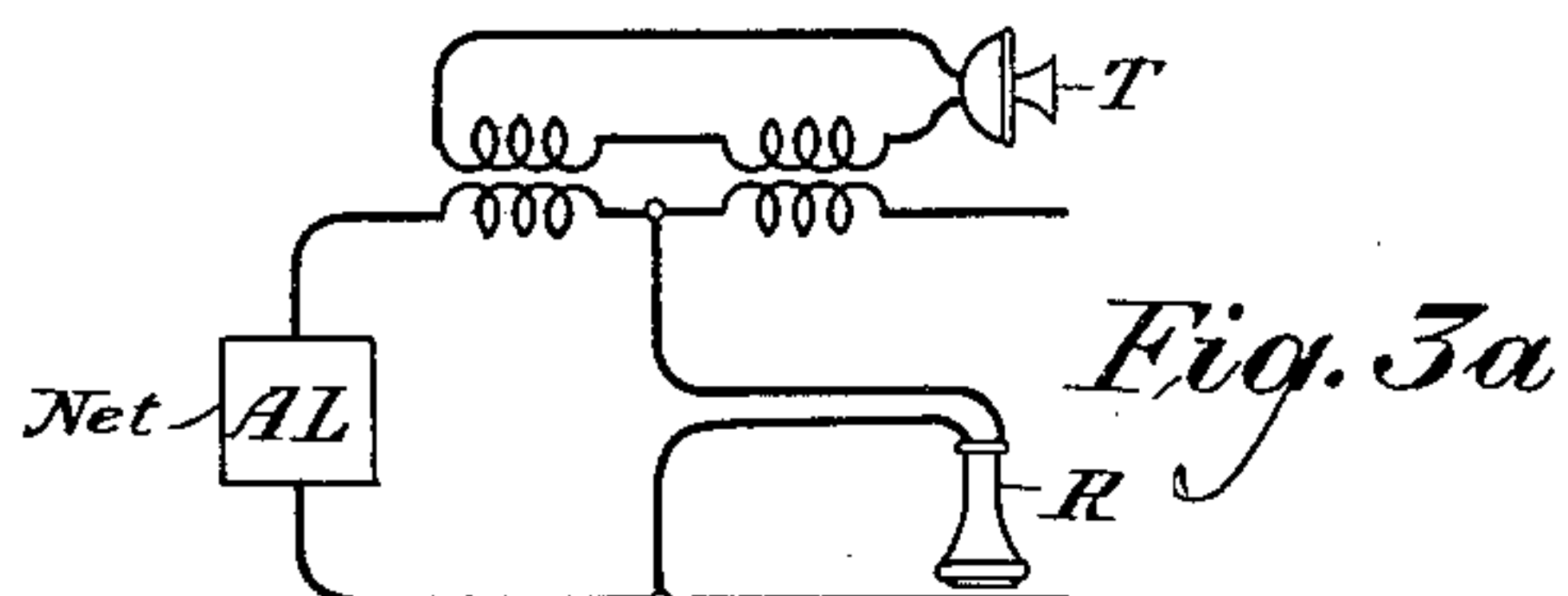
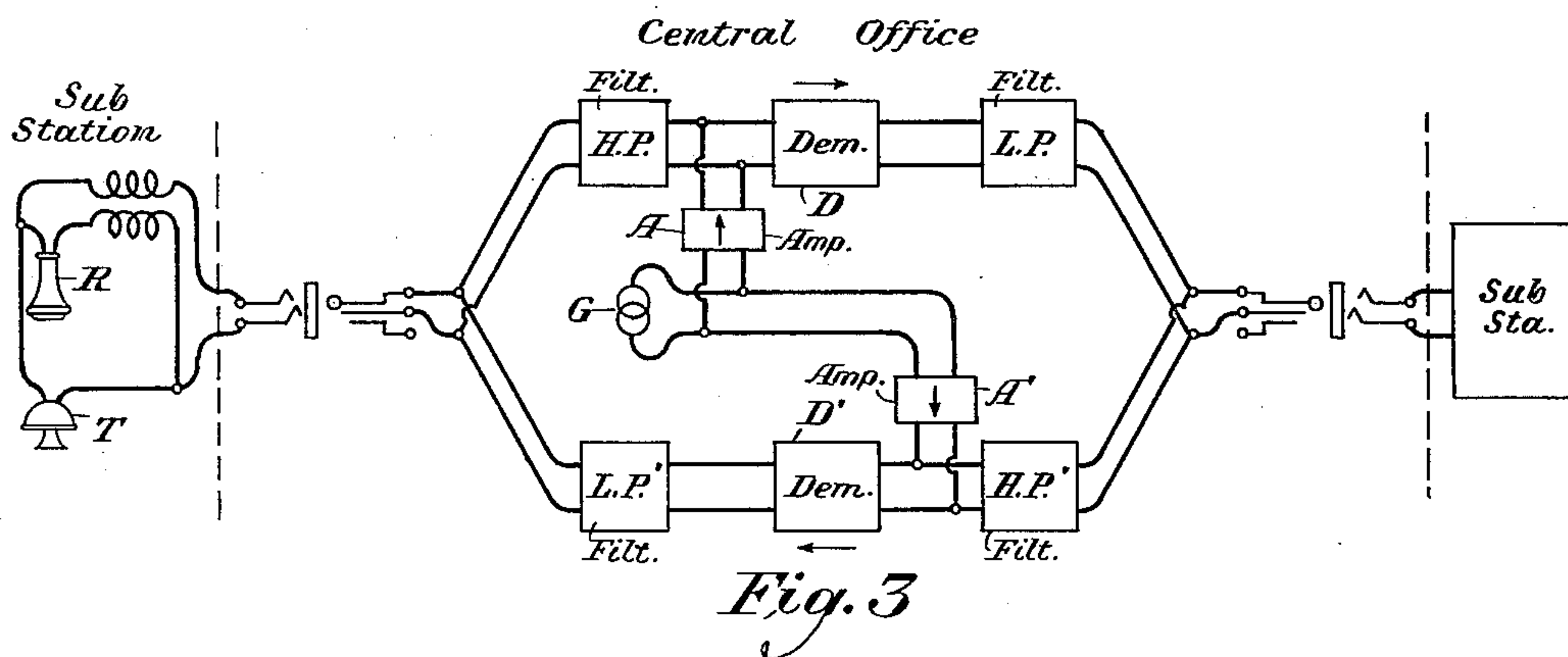
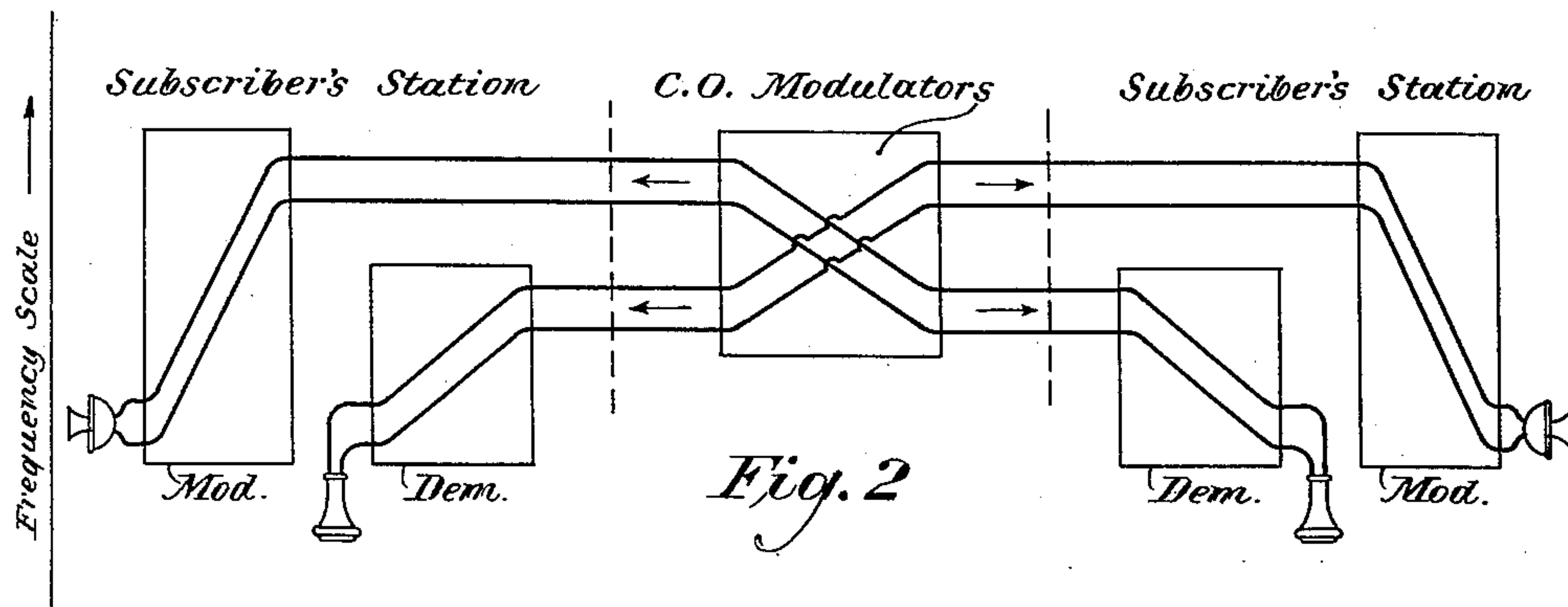
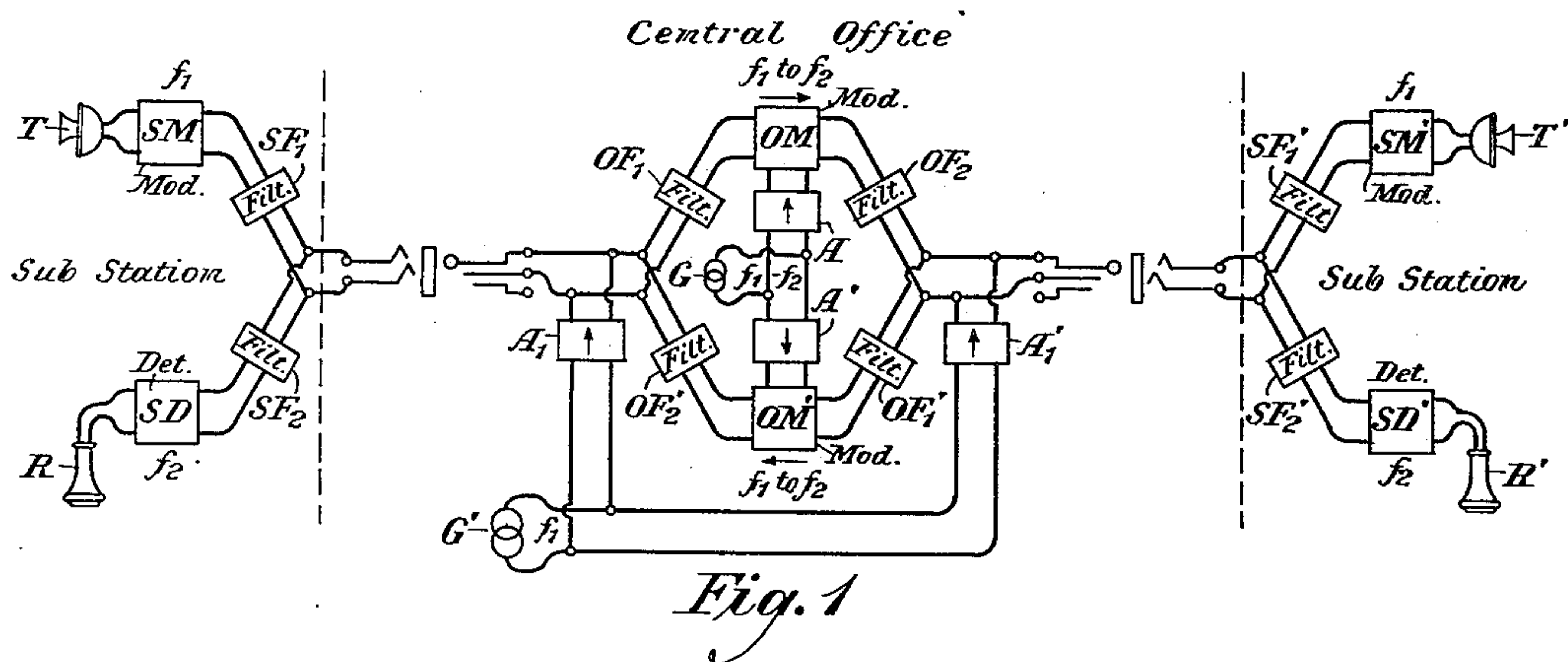
L. ESPENSCHIED

1,917,960

FOUR-WIRE CIRCUITS

Filed April 24, 1931

2 Sheets-Sheet 1



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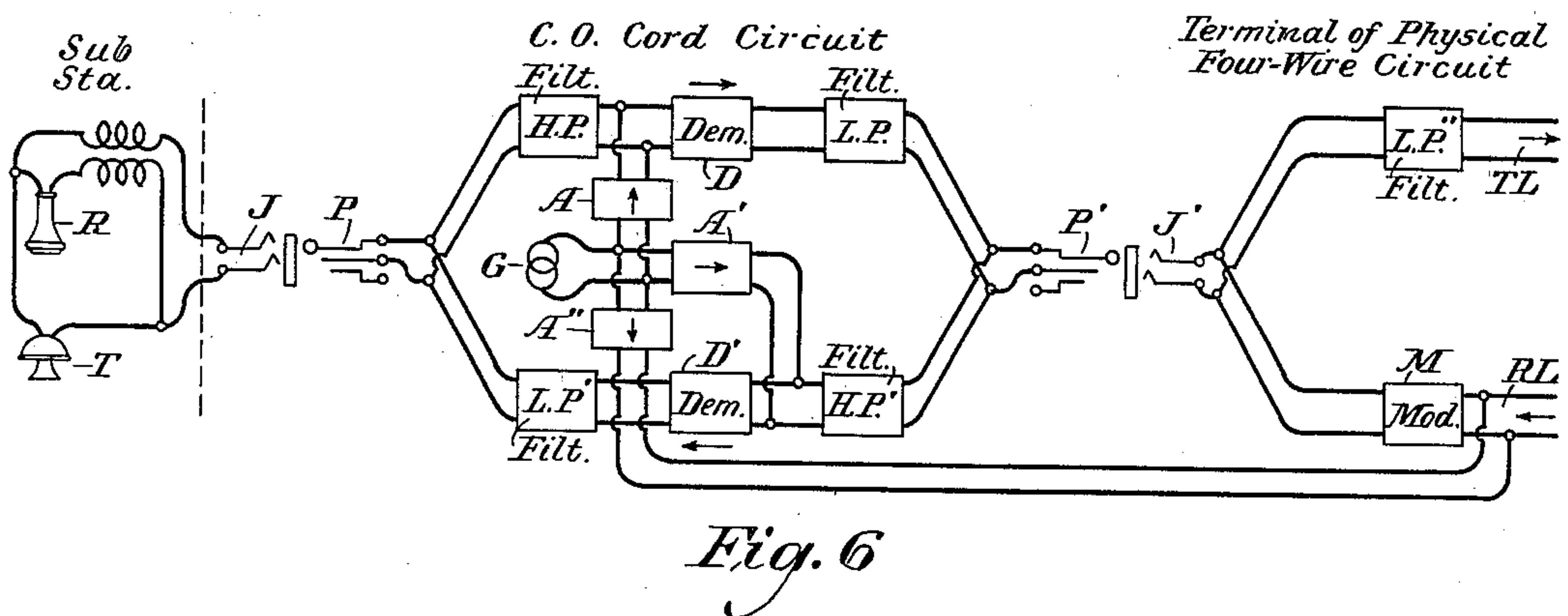
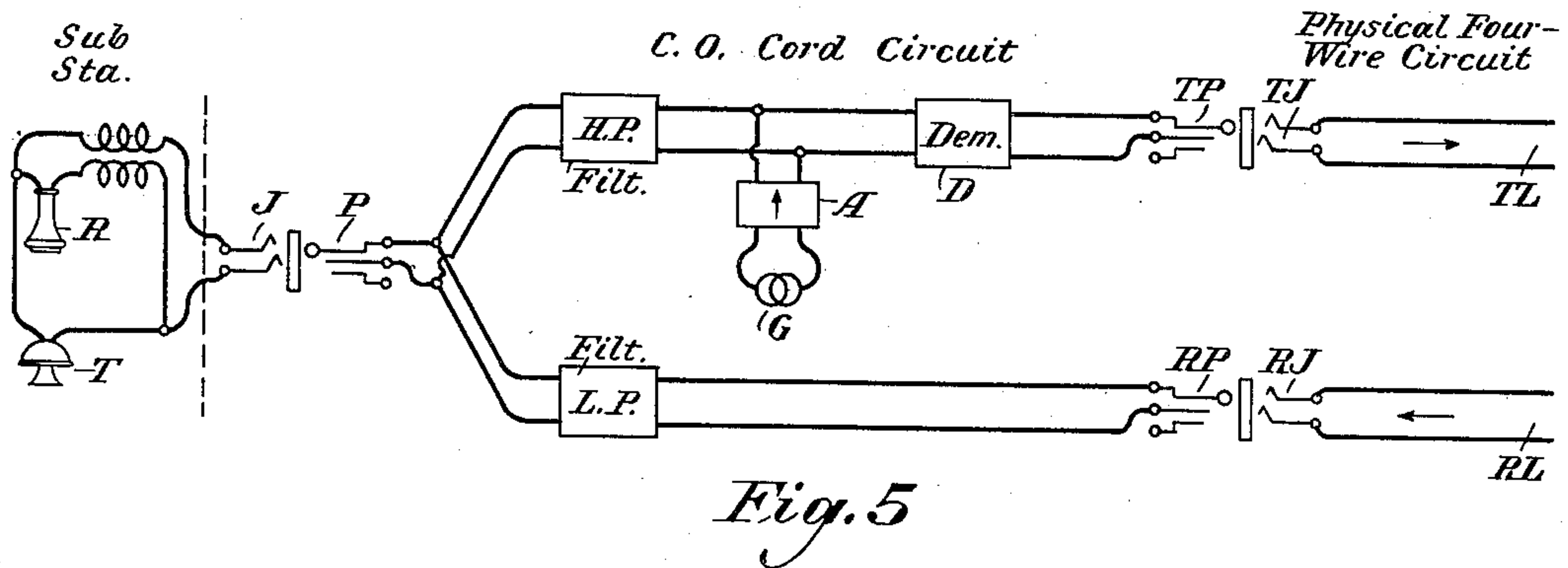
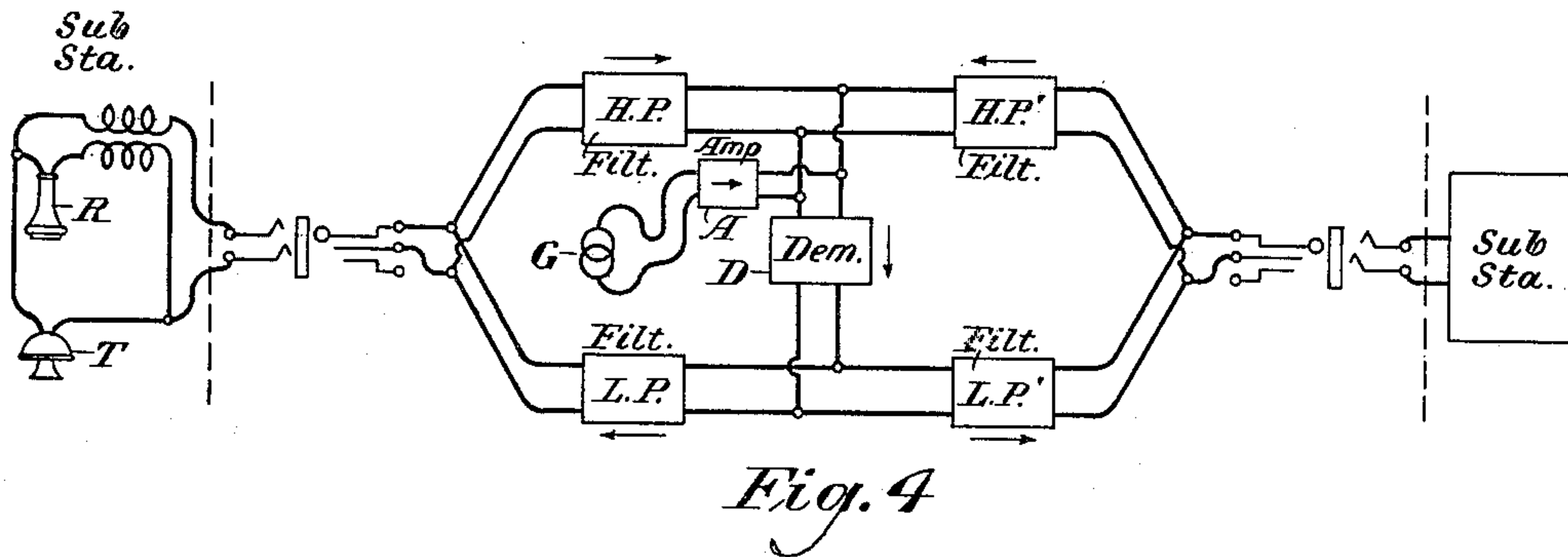
L. ESPENSCHIED

1,917,960

FOUR-WIRE CIRCUITS

Filed April 24, 1931

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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FOUR WIRE CIRCUITS

Application filed April 24, 1931. Serial No. 532,585.

This invention relates to transmission systems, and more particularly, to arrangements for obtaining the equivalent of four-wire operation in the local subscriber's circuits of a telephone system.

The type of local telephone circuit in general use today, employs one and the same transmission path for both sending and receiving. On the other hand, the present tendency in long distance telephone circuits is to employ separate transmission paths for transmission in opposite directions. These separate paths for opposite directional transmission may be physically distinct wire circuits as in the case of four-wire voice frequency transmission, or they may be paths of different frequencies derived from a single physical circuit as is done in carrier transmission. By analogy to the true four-wire method, the latter type of transmission has sometimes been called "equivalent four-wire" operation.

The reasons for employing two separate paths for opposite directional transmission in long distance circuits, are principally the desire to avoid the necessity for introducing balance at repeater points (such balance being difficult to secure and maintain, and being objectionable from the standpoint of echoes), and the desire to avoid near-end cross talk effects between the line circuits. The desire to employ four-wire operation in the long distance plant makes it desirable also to have four-wire operation in the local circuits when these are used for long distance connections. With the present practice, the fact that the local circuits are two-wire, imposes a serious handicap upon long distance four-wire operation.

Accordingly, it is proposed by the invention to obtain the equivalent of four-wire operation in the local plant including the subscriber's line, by the use of carrier frequencies for transmission in one or both directions over the local subscriber's circuits. In the preferred and most simple form of the invention, carrier transmission is used in one direction only, thus enabling the modulating, demodulating and carrier supply apparatus to be confined to the central office,

and permitting the subscribers' lines and sub-station circuits to be used in their present form.

The invention will now be more fully understood from the following description when read in connection with the accompanying drawings, in which Figure 1 shows a circuit arrangement embodying a form of the invention in which carrier transmission is employed in the local plant for transmission in both directions; Fig. 2 is a diagram showing the frequency translation involved in the transmission circuit of Fig. 1; Fig. 3 is a diagram of a system employing the principles of the invention in which carrier transmission is employed in the local plant in one direction, transmission in the opposite direction being at normal voice frequencies; Figs. 3a and 3b are sub-station circuit arrangements by which side tone effects in the receiver of the subscriber's sub-station circuit are eliminated; Fig. 4 is a diagram of a circuit arrangement embodying a form of the invention in which carrier transmission is employed for one direction, and transmission in the opposite direction takes place at ordinary voice frequency, and a common modulating or translating device is employed for both directions of transmission; Fig. 5 is a circuit diagram showing how with a system of the type of Fig. 3, the local subscriber may be connected to a physical four-wire trunk or long distance circuit, and Fig. 6 is a circuit diagram showing how the same type of cord circuit in Fig. 3 for local calls, may be used to connect the subscriber to a physical four-wire trunk or long distance circuit.

Referring to Fig. 1, a system is disclosed in which each subscriber transmits at one frequency level and receives at another frequency level. All subscribers in the exchange however, use the same carrier frequency for transmitting. All of the subscribers also receive at a common carrier frequency, but the carrier frequency employed for reception is different from that used for transmitting. As shown in Fig. 1, the subscriber's line terminates at the central office in the jack in the usual manner, but at the

subscriber's premises the two-wire line is branched into two two-wire circuits, one including a transmitter T, a modulator SM and a filter SF₁, and the other including a filter SF₂, a demodulator SD and a receiver R. The modulator is supplied with a carrier frequency f_1 , and the detector translates the received signal band from the receiving carrier f_2 to the normal voice level.

The filter SF₁ is, of course, arranged to transmit the carrier frequency f_1 and its associated side bands, and the receiving filter SF₂ is arranged to pass the carrier frequency f_2 and its associated side bands.

At the central office a cord circuit which terminates in two-wire plugs of the usual type, is provided with two branches, the west to east branch includes a filter OF₁ passing the carrier frequency f_1 and its associated side bands, a modulator OM and a filter OF₂ for passing the carrier frequency f_2 and its associated side bands. The east to west branch similarly contains a filter OF₁' for passing a carrier frequency f_1 and its associated side bands, a modulator OM' and a filter OF₂' for passing the carrier frequency f_2 and its associated side bands.

The modulators OM and OM' at the central office are supplied with a carrier frequency equal to the difference between the carrier frequencies f_1 and f_2 , this carrier frequency being supplied by a source G. In order to prevent cross talk in the adjacent cords supplied from the same carrier source, one-way devices A and A' are included in the leads from the generator G to the two modulators of the cord circuit. The carrier frequency to be employed in the transmitter branch at the subscriber's circuit is supplied by means of a source G' at the central office, and leads from this source are connected to the plugs of the cord circuit to energize the modulators such as SM and SM' at the subscriber's stations. In order to prevent the connections from the generator G₁ to the cord circuit from short-circuiting the four-wire operation of the cord circuit, and in order also to prevent cross talk in the other cords connected from the same carrier frequency source, the leads from the source G may include one-way devices such as A₁ and A₁'.

By means of this arrangement it will be apparent that the carrier frequencies employed in the transmitting branch at each subscriber's circuit, will be supplied over the subscriber's line from the central office, from the common source G'. The carrier frequency f_2 used for reception at each subscriber's station will be derived in the cord circuit modulators by beating the carrier frequency f_1 supplied to the cord circuit from the source G' with the frequency $f_1 - f_2$ supplied to the cord circuit from the source G. No carrier frequency source need

be provided at the subscriber's station. The resultant frequency translations taking place during transmission in the two directions will be as shown schematically in the diagram of Fig. 2, in which the stepping up and down of the frequencies in the frequency spectrum as transmission passes through the different parts of the system, are indicated.

The operation of the circuit of Fig. 1 will be as follows: In Fig. 1 the carrier frequency f_1 from the source G' is applied through the amplifier A₁ to the subscriber's line and is transmitted through the filter SF₁ to the output side of the modulator SM. The modulator SM may be of any well known type as, for example, a vacuum tube modulator, so that when the telephone transmitter T is actuated its grid potential is varied, thereby varying the impedance of the plate circuit of the modulator to the carrier frequency f_1 . Consequently, the carrier frequency is modulated and passes over the subscriber's line, through the filter OF₁ in the cord circuit, to the modulator OM. Here the modulated carrier current of frequency f_1 beats with the locally supplied carrier component $f_1 - f_2$ so that the modulated carrier f_1 is stepped down to the modulated carrier frequency f_2 which passes through the filter OF₂ in the cord circuit, to the subscriber's line at the right of the diagram. At the subscriber's station modulated carrier frequency f_2 passes through the filter SF₂' and enters the detector SD' which detects therefrom and transmits to the receiver R', the original signal generated at the transmitter T.

Transmission in the opposite direction is similar to that already described. The same carrier frequency f_1 is transmitted through the one-way device A₁' to the subscriber's line at the right and passes through the filter SF₁' to the modulator SM' where it is modulated by the voice waves from the transmitter T'. Modulated carrier frequency f_1 now passes over the subscriber's line and through the filter OF₁' of the cord circuit to the modulator OM'. The modulator steps the modulated carrier frequency f_1 down to the modulated carrier frequency f_2 which passes through the filter OF₂' to the subscriber's line at the left. At the subscriber's station the modulated carrier frequency f_2 passes through the filter SF₂ and is detected by the detector SD so that the signal corresponding to that generated by the transmitter T' is received in the receiver R.

The arrangement of Fig. 1 involves the use of modulating and detecting apparatus, as well as filters, at the subscriber's station, which makes the sub-station apparatus much less simple than the present sub-station apparatus, and furthermore, adds to its cost. These difficulties may be overcome

however, if in the two-wire parts of the system transmission takes place in one direction only at carrier frequency, and in the opposite direction the voice currents are transmitted at ordinary voice frequencies. An arrangement embodying these principles is shown in Fig. 3.

In this figure the subscriber's sub-set is of the standard type involving the usual transmitter T, receiver R and induction coil. The cord circuit at the central office however, involves two branches as before, each branch including demodulating apparatus as indicated at D and D'. The carrier frequency to be utilized for transmission in one direction is generated by a source G and is applied to the two sides of the cord circuit through one-way devices A and A' which serve the double purpose of preventing energy from being by-passed from one side of the cord circuit to the other, and of preventing cross talk from one cord circuit into another. This latter feature is especially important as all subscribers transmit at the same carrier frequency. Each side of the cord circuit is provided with filters, a high-pass filter HP being arranged on the input side of the demodulator D, and a low-pass filter LP being arranged on the output side of said demodulator. Similarly, in the opposite directional path of the cord circuit, filters HP' and LP' are arranged on the input and output sides respectively, of the demodulator D'.

In this system no special modulator is provided, but the subscriber's telephone transmitter is used as the modulator. The carrier frequency from the source G passes through the one-way device and through the high-pass filter HP over the subscriber's line to the subscriber's station at the left. The carrier frequency passes through both the subscriber's transmitter T and the subscriber's receiver R, but does not produce an audible sound in the latter because of its high frequency. When the subscriber speaks into the transmitter T however, the variable resistance of the transmitter causes variations in the amplitude of the carrier frequency flowing over the subscriber's line, with the result that the modulated carrier frequency passes through the filter HP into the demodulator D at the cord circuit. The demodulator D detects the signal corresponding to the transmitter T, and the detected voice currents pass through the low-pass filter LP to the subscriber's line at the right, the carrier frequency in the output of the demodulator being suppressed by the filter LP. At the subscriber's station at the right the voice currents at ordinary voice frequency pass into the telephone receiver in the usual manner.

In the case of transmission in the opposite

direction, the same carrier frequency from the source G passes through the high-pass filter HP' to the subscriber's line at the right. The subscriber's transmitter at the sub-station modulates the carrier frequency which passes through the filter HP' to the demodulator D'. The demodulator D' detects the original voice band which passes through the low-pass filter LP' over the subscriber's line to the receiver R of the subscriber's station at the left.

It will be noted, of course, that the subscribers' transmitters in this system are not energized by direct current, but are energized by the carrier frequency from the central office source G, the carrier frequency being supplied to the various cord circuits in a manner somewhat analogous to the common battery arrangement now commonly used in telephone systems. With the system of Fig. 3 there may be also some demodulation of the modulated carrier frequency resulting from the action of the transmitter T in the local receiver R which may act as a very inefficient demodulator. This would, of course, result in side tone in the receiver. Where it is desired to eliminate this side tone in accordance with the modern telephone practice, an anti-side-tone sub-station set of any well known type, such as shown at Fig. 3a, may be used in the system of Fig. 3. Here the subscriber's line is balanced by a network AL, and the receiver R is so connected as to be conjugate with respect to the transmitter T. If the carrier frequency is within the audible range, the carrier frequency currents, both modulated and unmodulated, may be heard in the receiver. An arrangement which may be employed to eliminate this effect, as well as side tone due to demodulation in the receiver, is shown in Fig. 3b. Here a low-pass filter LP_s is included in the receiver circuit to suppress the carrier frequency, both modulated and unmodulated.

In the arrangement of Fig. 3, separate demodulators were used in the two sides of the cord circuit for transmission in the two directions. Fig. 4 shows an arrangement in which the same demodulator D is employed for transmission in both directions. The demodulator D is connected in a bridge path between the two sides of the cord circuit, and the carrier frequency from the source G is supplied through a one-way device A to the input side of the demodulator. The arrangement of the filters is also somewhat different, as two high-pass filters are included in the upper branch of the cord circuit on either side of the demodulator connection, and two low-pass filters are included in the lower branch of the cord circuit on either side of the demodulator connection. The subscribers' sub-stations may be of standard type.

In operation, the carrier frequency from the source G is supplied to the subscribers' stations through the high-pass filters HP and HP', respectively. If the subscriber at the left speaks into his transmitter T the transmitter modulates the carrier frequency which passes through the high-pass filter HP of the cord circuit into the demodulator D. The demodulator D detects the original voice band from the modulated carrier, and voice currents are then transmitted through the low-pass filter LP' to the subscriber's station at the right where they are received in the usual manner. The demodulated voice frequencies of course, also pass through the low-pass filter LP back to the subscriber's line at the left, so that inherently this system will produce side tone in the receiver. When transmission takes place in the opposite direction, the modulated carrier current from the subscriber's station at the right passes through the high-pass filter HP' to the demodulator D which detects the voice currents therefrom and transmits them to the subscriber's lines through the low-pass filters LP and LP', as before.

It will be noted that in the arrangements above described, all of the sub-stations employ a common frequency band for transmitting and a different common frequency band for receiving. This prevents a near-end cross talk from the transmitting band of one subscriber into the receiving band of another.

The arrangements so far described involve apparatus for establishing connections between local subscribers whose lines terminate at the same exchange. For connection between a subscriber's line which operates on the equivalent four-wire principle above described and a long distance circuit using an actually physical four-wire operation, any one of several arrangements may be employed. For example, connection may be made by means of a special type of cord circuit as illustrated in Fig. 5. Here the cord circuit terminates at the subscriber's end in a single plug P which may be connected to the subscriber's jack J. The cord circuit is divided into a transmitting branch and a receiving branch, the transmitting branch terminating in a plug TP which may be connected to the transmitting side of a physical four-wire circuit by inserting the plug into a jack TJ. The receiving branch of the cord circuit similarly terminates in a plug RP which may be connected to the jack RJ of the receiving side of a physical four-wire circuit. The carrier frequency is supplied from a source G to the transmitting side of the cord circuit through an amplifier A. The transmitting side of the cord circuit also includes a demodulator D and a high-pass filter HP. A low-pass filter LP is connected in the receiving branch of the cord

circuit. It will be noted that the apparatus of this cord circuit involves just one-half of the apparatus of the cord circuit of Fig. 3.

In operation, the carrier frequency from the source G is supplied through the filter HP to the subscriber's line over the plug P and jack J. When the subscriber talks into the transmitter T the carrier frequency is modulated and passes through the filter HP to the demodulator D of the cord circuit. The demodulator D detects therefrom the voice band corresponding to the transmitter T, which is transmitted over the plug TP and jack TJ to the transmitting line TL of the four-wire circuit. At a distant exchange the voice frequency band transmitted over the line TL will pass into the receiving side of a cord circuit similar to that illustrated in Fig. 5, and thence through a filter corresponding to LP, to the distant subscriber station. In receiving from the distant station the transmission over the receiving line RL will be at voice frequencies whether the distant station is connected to an exchange of the ordinary battery type, or an exchange involving cord circuits of the type shown in Fig. 5. In the latter case, of course, a carrier frequency is modulated by the subscriber's transmitter and is then detected in the central office cord circuit before passing into the receiving line RL.

The arrangement of Fig. 5 involves the difficulty that the central office operator would have to use a different type of cord circuit for making long distance connections from that employed for ordinary intra-office connections. Fig. 6, however, shows how a cord circuit of the type shown in Fig. 3, may be employed for making both local and long distance connections. Here the cord circuit terminates in two-wire plugs P and P' at the two ends. The plug P may be inserted in the jack of a calling subscriber's line J, and the plug P' may be inserted into either the jack of a called subscriber's line as in Fig. 3, or into the two-wire jack J' to which the transmitting line TL and the receiving line RL of a physical four-wire circuit are joined. The physical four-wire circuit includes a low-pass filter LP'' in its transmitting line, and a modulator M in its receiving line. This is necessary because of the two-wire connection between the physical four-wire circuit and the four-wire part of the cord circuit, this two-wire circuit necessitating a translation of the voice frequency to a carrier frequency for transmission in one direction. The modulator M in the receiving line of the four-wire circuit will be supplied with the same carrier frequency as is supplied to the cord circuit. For this purpose the carrier source G is connected through a one-way device A'' to the receiving side of the physical four-wire circuit.

In operation, the carrier frequency from the source G passes through the one-way device A and the high-pass filter HP to the subscriber's line at the left. When the subscriber talks into his transmitter T this carrier frequency is modulated and the modulated carrier current passes through the high-pass filter HP to the demodulator D which detects therefrom the voice band corresponding to that generated at the transmitter T. This low frequency voice band now passes through the low-pass filter LP, over the plug P' and the jack J' to the transmitting line TL, passing through filter LP'' to the distant terminal of the four-wire circuit. The voice band thus transmitted cannot be transmitted over the receiving line RL, as the one-way modulator M prevents such action. A voice band transmitted from the terminal of the physical four-wire circuit comes in over the receiving line RL and modulates in the modulator M the carrier frequency supplied from the source G through the one-way device A''. The modulated carrier current now passes over the jack J' and plug P' to the lower side of the cord circuit, being prevented from entering the transmitting line by reason of the low-pass filter LP''. The high-pass filter HP' in the lower side of the cord circuit passes the modulated carrier frequency to the demodulator D' which detects therefrom the voice band corresponding to that generated at the distant station, and the voice band now passes through to the subscriber's station, and is received by the subscriber's receiver R in the usual manner.

It will be obvious that the general principles herein disclosed may be employed in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a system in which a plurality of subscribers' lines are arranged to be interconnected in pairs for two-way conversation through the same switching exchange, the method which consists in transmitting from the subscriber's station over all of the lines in the same frequency range, and receiving at the subscriber's stations over all of the lines in a different common frequency range to that used for transmitting.

2. In a system in which a plurality of subscriber's lines are arranged to be interconnected in pairs for two-way conversation through the same switching exchange, the method which consists in transmitting from the subscriber's station over all of the lines in the same frequency range, receiving at the subscriber's station over all of the lines in a different common frequency range to that used for transmitting, and translating

from the one frequency range to the other at the central station.

3. In a system in which two subscriber's lines may be interconnected for two-way conversation through a central office, the method which consists in transmitting in one direction over the subscriber's line from one subscriber's station to the central office in one frequency range, translating at the central office to another frequency range, transmitting over the second line to the second subscriber's station in said second frequency range, transmitting in the opposite direction from the second subscriber's station over his line to the central office in said first frequency range, translating at the central office to said second frequency range, and transmitting over the first subscriber's line from the central office in said second frequency range.

4. In a system in which a plurality of subscribers' lines are arranged to be interconnected in pairs for two-way conversation through the same switching exchange, the method which consists in transmitting from the subscriber's station over all of the lines in the same carrier frequency range, and receiving at the subscriber's station over all of the lines in the voice frequency range.

5. In a system in which a plurality of subscribers' lines are arranged to be interconnected in pairs for two-way conversation through the same switching exchange, the method which consists in transmitting from the subscriber's station over all of the lines in the same carrier frequency range, receiving at the subscriber's station over all of the lines in the voice frequency range, and translating from one of said ranges to the other range at the central office.

6. In a system in which two subscribers' lines may be interconnected for two-way conversation through a central office, the method which consists in transmitting in one direction over the subscriber's line from one subscriber's station to the central office in a carrier frequency range, translating at the central station to the voice frequency range, transmitting over the second line to the second subscriber's station in said voice frequency range, transmitting in the opposite direction from said second subscriber's station over his line to the central office in the same carrier frequency range as was employed by said first line, translating at the central office to the voice frequency range, and transmitting over said first subscriber's line from the central office in the voice frequency range.

7. In a transmission system, a central office, a plurality of subscriber's lines adapted to be interconnected in pairs for two-way conversation through said central office, means to transmit voice signals over said lines to the central office in the same fre-

quency range, and means to receive voice signals from the central office over said lines in a different common frequency range than is used for transmitting.

5 8. In a transmission system, a central office, a plurality of subscribers' lines adapted to be interconnected in pairs for two-way conversation through said central office, means to transmit voice signals over said
10 lines to the central office in the same frequency range, means to receive voice signals from the central office over said lines in a different common frequency range than is used for transmitting, and means at the central
15 office to translate the two channels of a two-way conversation over any pair of connected lines from one frequency range to the other.

9. In a transmission system, a central office, a pair of subscribers' lines adapted to be
20 connected for two-way conversation through said central office, means to transmit over the subscriber's line from one subscriber's station to the central office in one frequency range, means to translate to another frequency
25 range at the central office, means to transmit over the second line from the central office to the second subscriber's station in said second frequency range, means to transmit in the opposite direction from the
30 second subscriber's station over his line to the central office in the first frequency range, means to translate at the central office to said second frequency range, and means to transmit over said first subscriber's line from the
35 central office in said second frequency range.

10. In a transmission system, a central office, a plurality of subscribers' lines adapted to be interconnected in pairs for two-way
40 conversation through said central office, means to transmit voice signals over said lines to the central office in the same carrier frequency range, and means to receive over said lines in the voice range.

11. In a transmission system, a central
45 office, a plurality of subscribers' lines adapted to be interconnected in pairs for two-way conversation through said central office, means to transmit voice signals over said lines to the central office in the same carrier frequency range, means to receive
50 over said lines in the voice range, and means at the central office to translate from one of said ranges to the other.

12. In a transmission system, a central
55 office, a pair of subscribers' lines adapted to be connected for two-way conversation through said central office, means to transmit over the subscriber's lines from one subscriber's station to the central office in a carrier frequency range, means at the central
60 office to translate to the voice frequency range, means to transmit over the second line from the central office to the second subscriber's station in said voice frequency range, means to transmit in the opposite di-

rection from the second subscriber's station over his line to the central office in said carrier frequency range, means to translate said carrier range at the central office to the voice frequency range, and means to transmit
70 over said first subscriber's line from the central office in the voice frequency range.

13. In a transmission system, a subscriber's station, a central office, a subscriber's
75 line extending from the subscriber's station to the central office, a four-wire long distance circuit including a transmitting channel and a receiving channel associated with said central office, means to transmit from
80 said subscriber's station over the subscriber's line to the central office in one frequency range, means to apply waves corresponding to the waves so transmitted to the transmitting channel of the four-wire circuit, means
85 to receive waves from the receiving channel of the four-wire circuit at said central office, and means to transmit waves corresponding to the waves so received over the subscriber's line to the subscriber's station in a frequency
90 range different from said first frequency range.

14. In a transmission system, a subscriber's station, a central office, a subscriber's
95 line extending from the subscriber's station to the central office, a four-wire long distance circuit including a transmitting channel and a receiving channel associated with said central office, means to transmit from said subscriber's station over the subscriber's line to the central office in one frequency range, means to apply waves corresponding to the waves so transmitted to the transmitting channel of the four-wire circuit, means to receive waves from the receiving
105 channel of the four-wire circuit at said central office, means to transmit waves corresponding to the waves so received over the subscriber's line to the subscriber's station in a frequency range different from said first frequency range, and means at the
110 central station for translating from one frequency range to the other.

15. In a transmission system, a subscriber's station, a central office, a subscriber's
115 line extending from the subscriber's station to the central office, a four-wire long distance circuit including a transmitting channel and a receiving channel associated with said central office, means to transmit from said subscriber's station over the subscriber's line to the central office in a carrier frequency range, means to apply waves corresponding to the waves so transmitted to the transmitting channel of the four-wire circuit, means to receive waves from the receiving
120 channel of the four-wire circuit at said central office, and means to transmit waves corresponding to the waves so received over the subscriber's line to the sub-
125
130

scriber's station in the normal voice frequency range.

16. In a transmission system, a subscriber's station, a central office, a subscriber's line extending from the subscriber's station to the central office, a four-wire long-distance circuit including a transmitting channel and a receiving channel associated with said central office, means to transmit from said subscriber's station over the subscriber's line to the central office in a carrier frequency range, means to apply waves corresponding to the waves so transmitted to the transmitting channel of the four-wire circuit, means to receive waves from the receiving channel of the four-wire circuit at said central office, means to transmit waves corresponding to the waves so received over the subscriber's line to the subscriber's station in the normal voice frequency range, and means at the central station for translating from one frequency range to the other.

17. In a transmission system, a central office, a plurality of subscribers' stations, lines extending from the subscribers' stations to the central office, link circuits at the central office to connect the lines in pairs for two-way transmission, means associated with two-way transmission, means associated with the link circuit to supply the same carrier frequency over two interconnected lines to the substations, means at each substation to modulate the carrier in accordance with speech, and means associated with the link circuit to translate the modulated carrier received from each line into normal voice frequency currents for transmission over the other line.

18. In a transmission system, a central office, a plurality of subscribers' stations, lines extending from the subscribers' stations to the central office, link circuits at the central office to connect the lines in pairs for two-way transmission, means associated with the link circuit to supply the same carrier frequency over two interconnected lines to the substations, means at each substation to modulate the carrier in accordance with speech, and means associated with the link circuit to translate the modulated carrier received from each line to a different common frequency range for transmission over the other line.

19. In a transmission system, a central office, a plurality of subscribers' stations, lines extending from said subscribers' stations to said central office, a four-wire long-distance circuit including a transmitting

channel and a receiving channel associated with said central office, link circuits at the central office to connect the lines in pairs for two-way transmission or to connect any line to said four-wire circuit for long-distance two-way transmission, means associated with said link circuit when interconnecting two subscribers' lines to supply the same carrier frequency over the two interconnected lines to the subscribers' stations, means at each substation to modulate the carrier in accordance with speech, means associated with the link circuit to translate the modulated carrier received from each line into waves of normal voice frequency range for transmission over the other line, said link circuit having means to apply the waves in a translated frequency range to the transmitting channel of the four-wire circuit and to apply waves received from the receiving channel of the four-wire line to the subscriber's line in the common frequency range employed for transmission from the central office over the subscriber's line to the substation.

20. In a transmission system, a central office, a plurality of subscribers' stations, lines extending from said subscribers' stations to said central office, a four-wire long-distance circuit including a transmitting channel and a receiving channel associated with said central office, link circuits at the central office to connect the lines in pairs for two-way transmission or to connect any line to said four-wire circuit for long-distance two-way transmission, means associated with said link circuit when interconnecting two subscribers' lines to supply the same carrier frequency over the two interconnected lines to the subscribers' stations, means at each substation to modulate the carrier in accordance with speech, means associated with the link circuit to translate the modulated carrier received from each line into waves of a different common frequency range for transmission over the other line, said link circuit having means to apply the waves in a translated frequency range to the transmitting channel of the four-wire circuit and to apply waves received from the receiving channel of the four-wire line to the subscriber's line in the common frequency range employed for transmission from the central office over the subscriber's line to the substation.

In testimony whereof, I have signed my name to this specification this 21st day of April 1931.

LLOYD ESPENSCHIED.