G. K. THOMPSON.

MEANS FOR EQUALIZING TRANSMISSION OVER LINES OF DIFFERENT ELECTRICAL CHARACTERISTICS.

APPLICATION FILED OCT. 29, 1918.

1,415,907. Patented May 16, 1922.

2 SHEETS—SHEET 1.

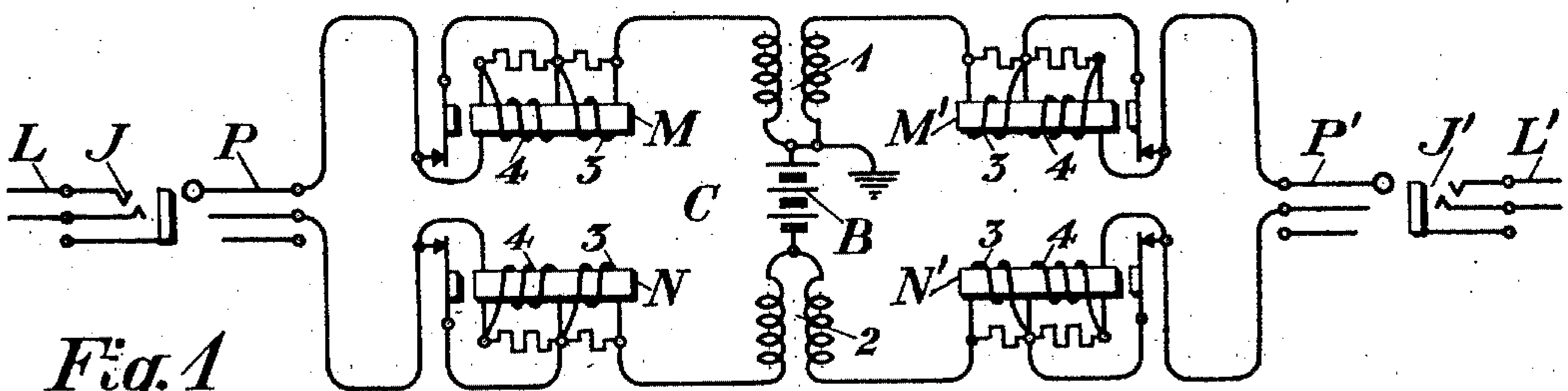

Fig. 1

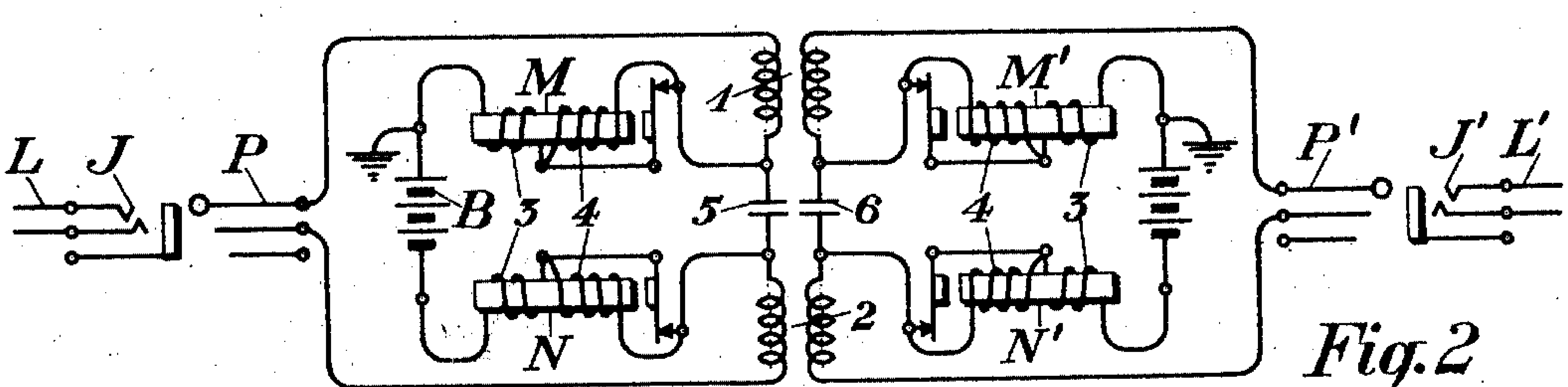

Fig. 2

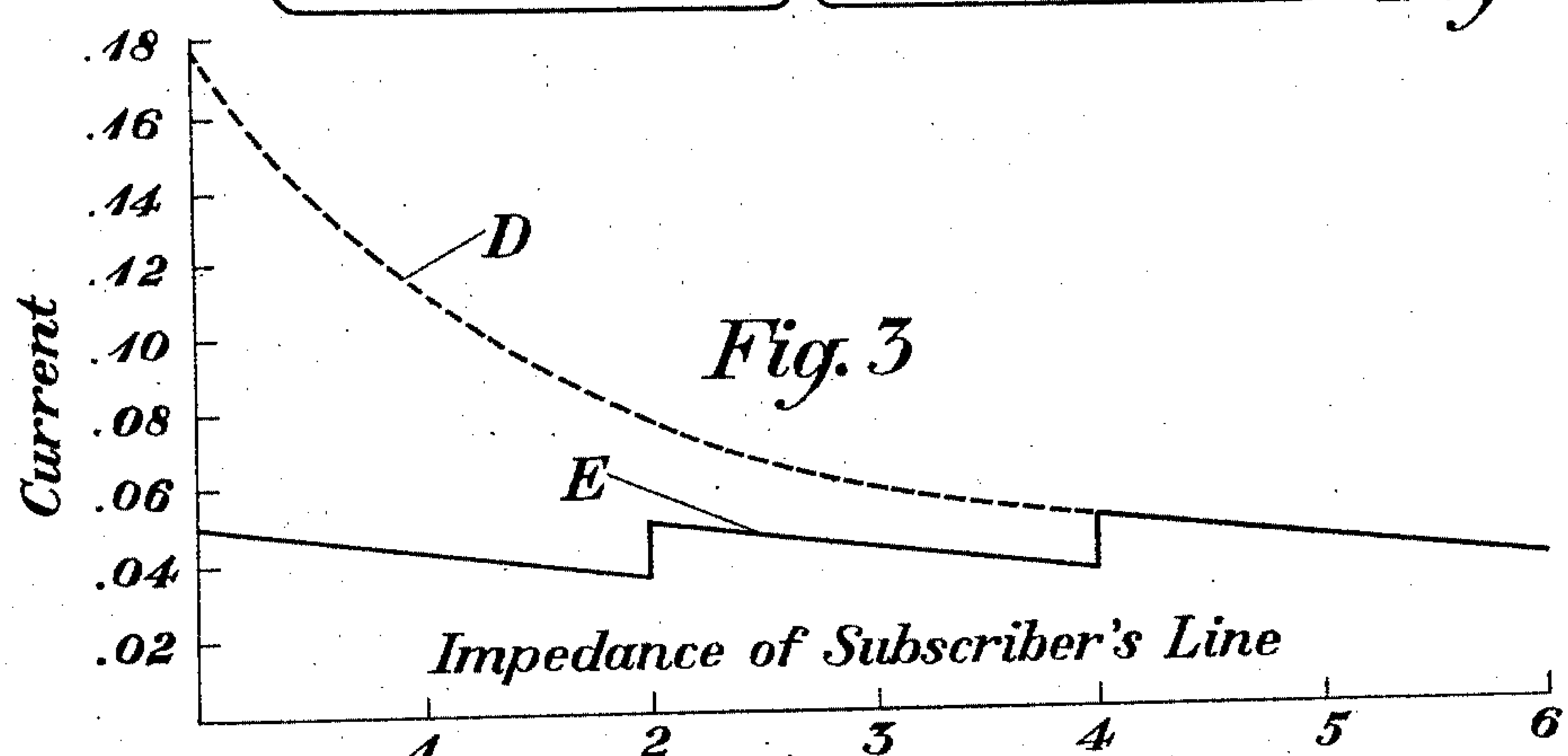

Fig. 3

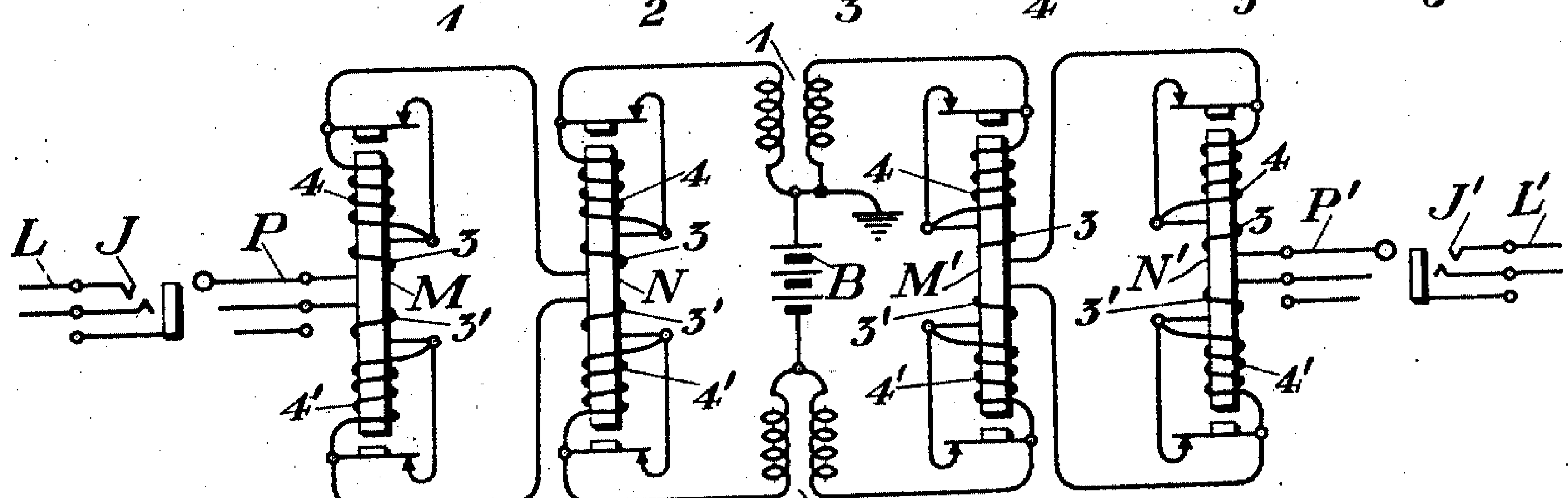

Fig. 4

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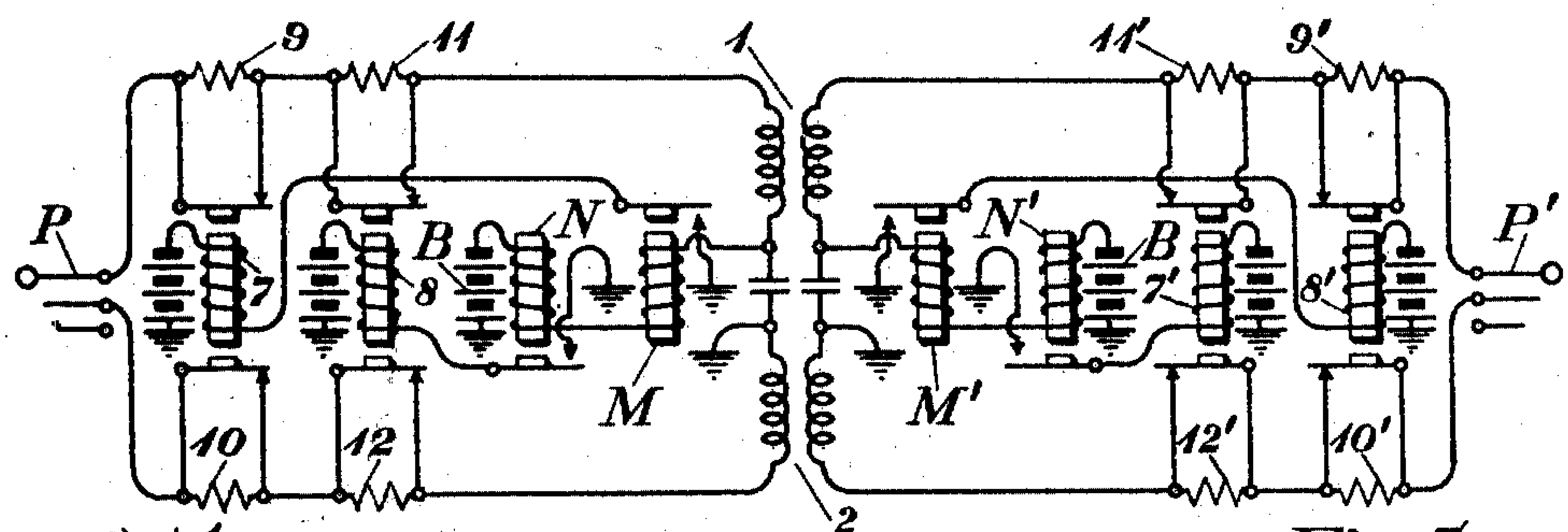

Fig. 5

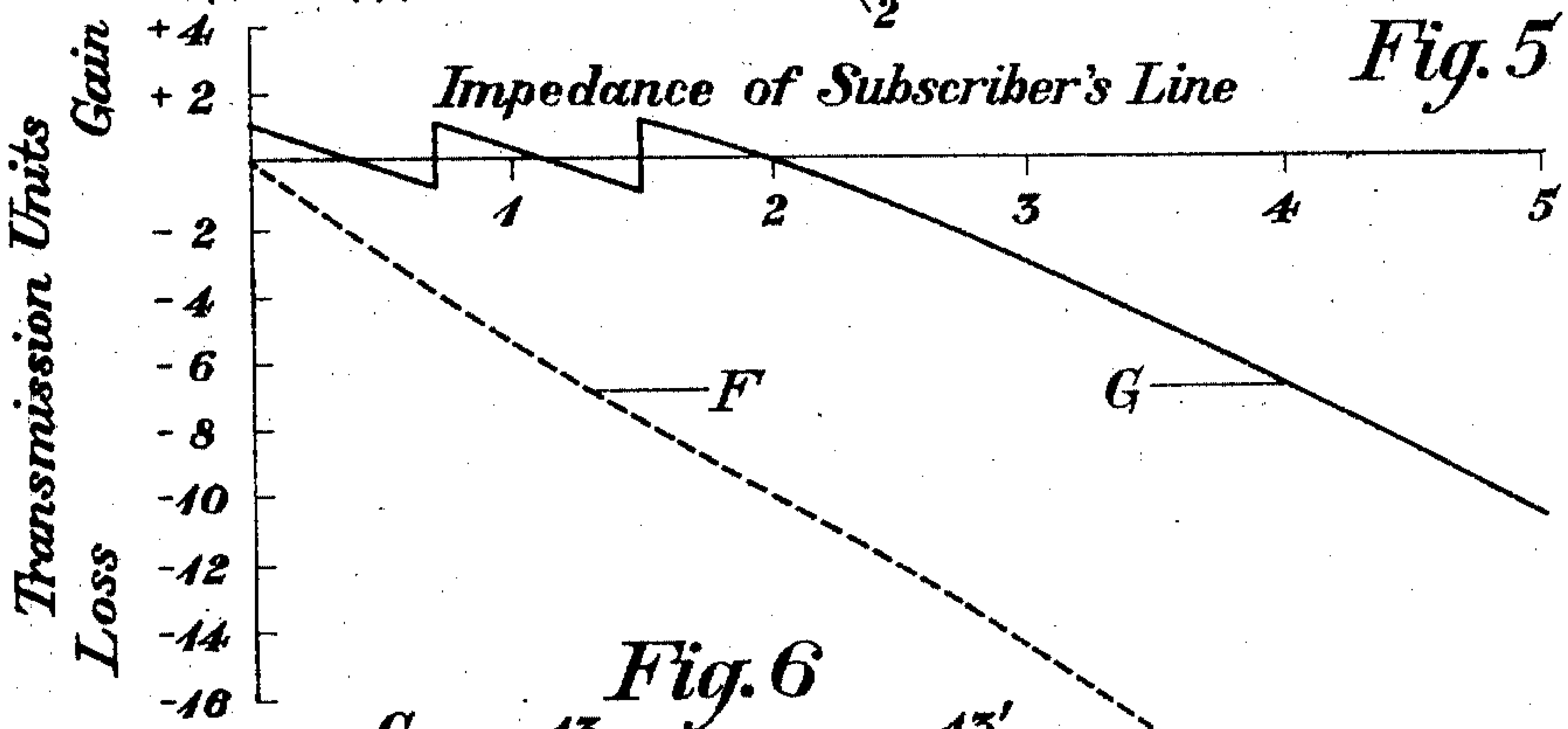

Fig. 6

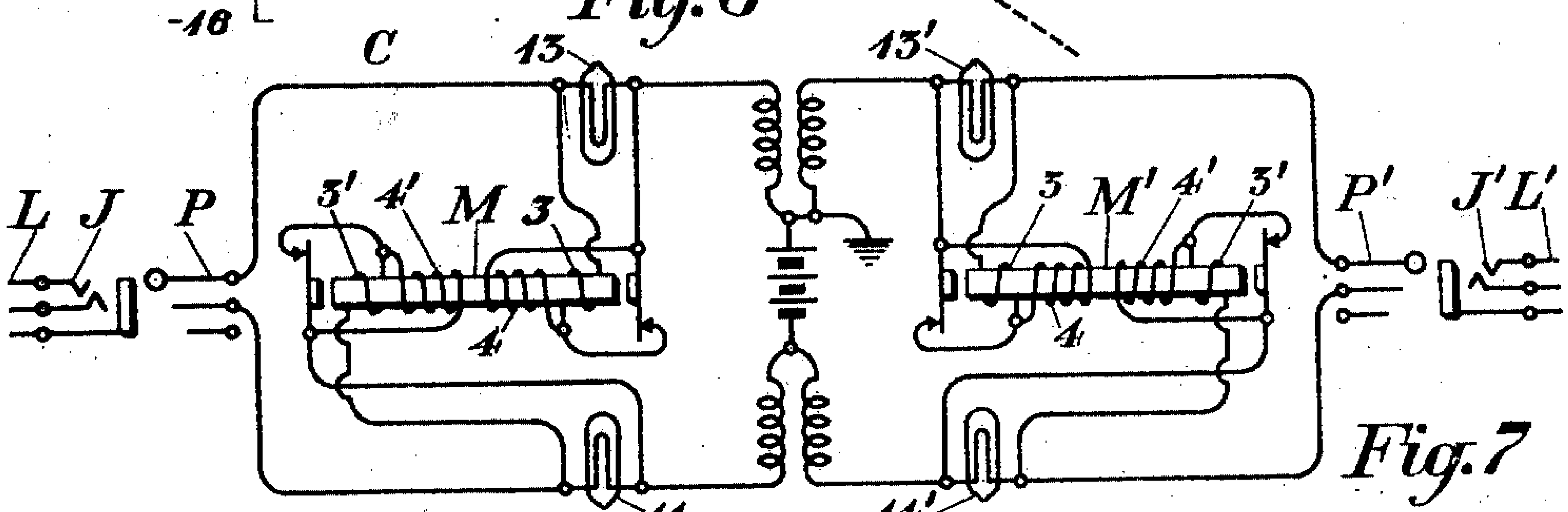

Fig. 7

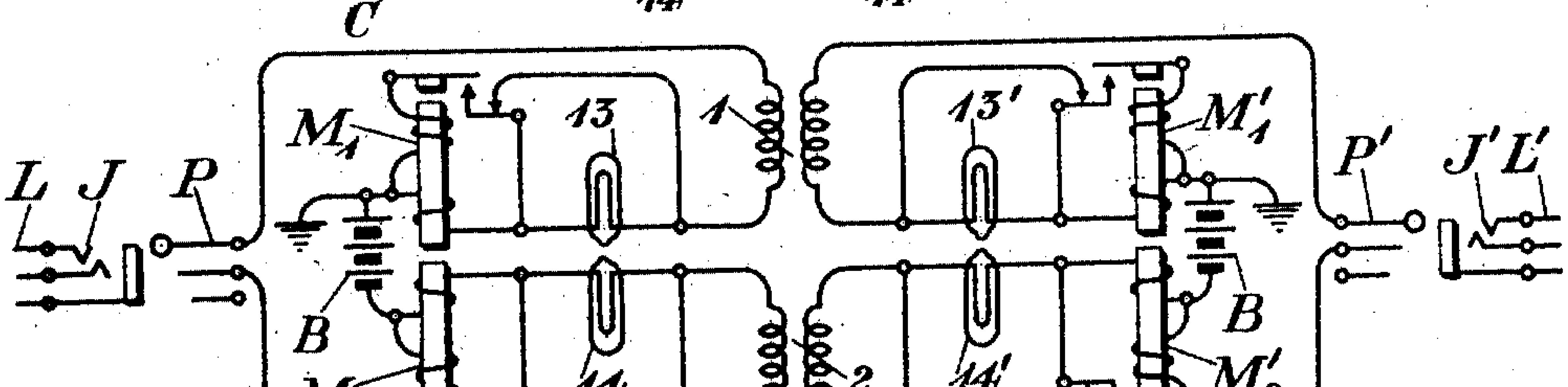

Fig. 8

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UNITED STATES PATENT OFFICE.

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MEANS FOR EQUALIZING TRANSMISSION OVER LINES OF DIFFERENT ELECTRICAL CHARACTERISTICS.

1,415,907. Specification of Letters Patent. **Patented May 16, 1922.**

Application filed October 29, 1918. Serial No. 260,150.

To all whom it may concern:

Be it known that I, George K. Thompson, residing at Maplewood, in the county of Essex and State of New Jersey, have invented certain Improvements in Means for Equalizing Transmission Over Lines of Different Electrical Characteristics, of which the following is a specification.

This invention relates to telephone systems and more particularly to the provision of means whereby the electrical characteristics of telephone lines may be equalized or rendered more uniform.

Telephone lines have, in general, different electrical characteristics varying with the length of the lines. These variations in the electrical characteristics of different subscribers' lines in a telephone system, introduce a number of variable effects in the telephone service to the different stations. For example, the different electrical characteristics result in different degrees of attenuation of the alternating telephone current passing over the subscribers' lines, thus providing louder and more effective telephonic communication for subscribers connected by means of short lines than for subscribers connected by means of long lines. Furthermore, in the common battery systems now so generally employed in all but the small communities, the resistance of the line causes a further effect on the transmission, in that it reduces the amount of direct current which the transmitter receives from the central office battery and so renders it less efficient in the generation of the alternating telephone current. Likewise, in common battery systems employing electro-magnetic receivers—that is, receivers not including a permanent magnet but depending for their energization upon the current supply,—this variation in current supply introduces changes in the efficiency of the receiver. It is one of the objects of this invention to reduce and substantially eliminate the difficulties above mentioned, although other and further objects of the invention will be clear from the detailed description hereinafter given.

These objects are secured in accordance with the present invention by providing a cord circuit or other form of link connector employed for establishing intercommunication between different transmission lines, with impedance or resistance elements, the impedance of which is automatically adjusted by means of marginal relays as the current flowing over the lines tends to increase or decrease. Preferably these impedance elements are normally short circuited so that for very long lines no additional impedance is introduced, but when the cord circuit is associated with a shorter line the resultant increase in current flow energizes and locks up one or more marginal relays, thereby removing the short circuits from a sufficient number of impedance elements to reduce the current flow to the desired value. The impedance elements may, if desired, be locked in such manner as to impede both the flow of direct current and the flow of the alternating signaling currents generated at the subscriber's station.

As a further refinement, ballast lamps provided with filaments of tungsten, iron or other material having a positive temperature-resistance co-efficient may be used as impedance elements, thereby producing a further equalization between the steps introduced by the action of the marginal relays. By employing ballast lamps which are normally short circuited or shunted, the additional loss due to the introduction of these lamps in circuit with long lines may be eliminated. Furthermore, the substantially uniform transmission obtained by this system may be made equal to or better than the average transmission heretofore obtained by the increased efficiency of the telephone transmitter which now becomes possible owing to the uniform current supply obtained. Moreover, the transmission may be increased by the employment of more efficient electro-magnetic receivers under more advantageous conditions than have heretofore existed. Other means for increasing the transmission may also be used, such as, for instance, increasing the potential of the source of current supply.

The invention may now be more clearly understood from the following description when read in connection with the accompanying drawings Figures 1, 2, 4, 5, 7 and 8 of which constitute circuit diagrams of six different modifications of the invention, while Figs. 3 and 6 are curves illustrating certain features of the operation.

Referring to Fig. 1, a cord circuit C is shown provided with plugs P and P′, adapted to co-operate with the jacks of a plurality of subscribers' lines, such as, for instance, the jacks J and J′ of subscribers' lines L and L′. The cord circuit is provided with the usual source of direct current supply B and with the transformers or repeating coils 1 and 2 for transmitting alternating telephone currents coming in over one subscriber's line to the other subscriber's line. For the purpose of equalizing transmission, marginal relays M, N, M′ and N′ are provided in the talking conductors of the cord circuit. Each of these marginal relays has a low resistance winding 3 normally included in the current supply circuit and a high resistance winding 4 which is normally short circuited over the back contact of the relay. In order to reduce transmission losses due to the windings of the relays, the windings may be shunted by non-inductive resistances, if desired.

The operation of the circuit may now be understood by reference to the curves in Fig. 3. In this figure, the curve D represents the variation of direct current flow with the variation in the impedance of subscribers' lines. It will be noted that the current flow is less for long lines and increases rather rapidly as the impedance of the line decreases. If the cord circuit of Fig. 1 is associated with a line whose impedance lies between points 4 and 6, neither of the marginal relays M and N will be operated and the current supply will be somewhere between .036 and .05. When the cord circuit is associated with a line whose impedance lies between points 2 and 4, the current flow will initially be between .05 and .077. This current flow is sufficient to energize the windings 3 of relay M which thereupon opens the short circuit normally existing about its high resistance winding 4 so that the high resistance winding is now included in the current supply path and the current at once falls as shown by the curve E, to a value lying between .036 and .05. This current flow through windings 3 and 4 in series is sufficient to retain the relay M energized. When the cord circuit is associated with a line whose impedance lies between points zero and 2, the initial current flow will be between .077 and .178. This current flow is sufficient to energize both relays M and N through their low resistance windings, so that the short circuits about the high resistance windings are opened and the high resistance windings of both relays are included in circuit with the source of current supply and the current at once falls to a value lying between .036 and .05, as shown by the curve E.

The initial impulse of current is considerably higher than that normally obtained but is not of sufficiently long duration to cause any injury to the telephone instrument. The marginal action of the relays insures that the current supply will always be maintained within certain limits, regardless of the length of the line, and by providing a sufficient number of relays and properly proportioning the resistances controlled by the relays, any desired current flow may be obtained. The relay M is so adjusted as to be somewhat slower in its action than the relay N to prevent the possibility of the relay M operating on a short line and thereby reducing the current sufficiently to prevent the operation of the relay N. The operation of the relays M′ and N′ is the same as relays M and N and need not be further described.

A slightly modified form of circuit is shown in Fig. 2 which differs from that of Fig. 1 in that the relays M, N, M′ and N′ are included between the battery source B and the windings of the induction coils 1 and 2, instead of being included directly in the talking circuit, a low impedance path for talking currents being provided through the condensers 5 and 6. In this case it is unnecessary to shunt the windings 3 and 4 of the relays by non-inductive resistances in order to reduce transmission losses. The operation of the circuit is similar to that of Fig. 1 and need not be further described.

The arrangements shown in Figs. 1 and 2 are open to the objection that the two sides of the cord circuit are not balanced when one of the relays is operated. This objection is overcome by means of the arrangement shown in Fig. 4, in which relays M, N, M′ and N′ are each provided with four windings, two low resistance windings 3 and 3′ and two high resistance windings 4 and 4′, one low resistance winding being normally included in each conductor of the cord circuit when the relay is not operated and one low resistance winding and one high resistance winding being included in each conductor of the cord circuit when the relay is in the operated position. By arranging the relays in this manner both the high and low resistance windings are divided and half of the resistance of each is included in each talking conductor so that a complete balance is obtained. As in the case of Figs. 1 and 2, the relay M responds to a medium increase in current and both relays M and N to a large increase in current, the relay N being slightly quicker in its action than the relay M. The circuit of Fig. 4 also differs from that of Fig. 1 in that the windings are not shunted by non-inductive resistances, so that the impedances of the windings themselves serve to equalize the transmission of alternating telephone current as well as the supply of direct current.

A still further arrangement is illustrated in Fig. 5. In this case the windings of relays are not utilized to furnish the impedance elements for the cord circuits, but simple resistances 9, 10, 11 and 12 and 9′, 10′, 11′ and 12′ are included in the two sides of the cord circuit in such a manner that a balance will always be obtained. Resistances 9 and 10 are normally shunted by the contacts of relay 7, while resistances 11 and 12 are normally shunted by relay 8. In a similar manner, the resistances 9′, 10′ and 11′, 12′, respectively, are controlled by the relays 8′ and 7′. Battery supply current is furnished through the windings of marginal relays M and N, for one end of the cord circuit, while the other end of the cord circuit is supplied through the windings of marginal relays M′ and N′. Relay M controls the circuit of relay 7, while relay N controls the circuit of relay 8, the relay N being slightly quicker in its action than the relay M. In a similar manner, relays M′ and N′ control the circuits of relays 7′ and 8′. The resistances 9, 10, 11, 12, etc., are included in the cord circuit in such a manner as to impede both the flow of direct current and of alternating telephone current generated at the subscriber's station.

The operation of the circuit of Fig. 5 may be understood from a consideration of the curves shown in Fig. 6, in which the curve F represents the variation in transmission with variation of the impedance of subscribers' lines which are not provided with equalizing means. Representing the transmission obtained under the zero loop condition as zero and plotting the losses obtained over long loops in suitable transmission units, it will be seen that the transmission, as indicated by the curve F, decreases with the increase in the impedance of the subscriber's line. Where the cord circuit is provided with equalizing resistances, as shown in Fig. 5, however, both marginal relays M and N will be operated upon loops from zero to loops having impedance of three-quarters of a unit. Relays 7 and 8 are energized over the front contacts of relays M and N and open the short circuits normally existing about the resistances 9, 10 and 11, 12, respectively, connected to the cord circuit of Fig. 5. The transmission obtained over such loops employing instruments of improved efficiency as shown by the curve G, will vary between one unit of gain and one unit of loss depending on the length of the loop.

For loops having impedance from three-quarters to one and one-half units, only the relay M will be operated, thereby energizing relay 7 to remove the short circuits from resistances 9 and 10. The impedance of the circuit is now increased so that the transmission will again vary between one unit of gain and one unit of loss. For all loops having an impedance greater than one and one-half units, neither relays M nor N receive sufficient current to energize their windings and, consequently, all of the resistances are short circuited. The transmission is, therefore, increased to a gain of one unit for a loop having impedance of one and one-half units, from which point the transmission falls off to zero for lines having an impedance of two units and for lines having still greater impedance, the transmission further falls off, as shown by the curve G.

Instead of inserting simple resistances in the two sides of the cord circuit, as in the case of Fig. 5, ballast lamps provided with filaments of tungsten, iron, or other material having a positive temperature-resistance coefficient may be employed as shown in Fig. 7. In this figure, ballast lamps 13 and 14 are included in the two sides of the circuit for one end of the cord and ballast lamps 13′ and 14′ are included in the two sides of the circuit for the opposite end. The ballast lamps 13 and 14 are normally shunted by the low resistance windings 3 and 3′ of the marginal relay M, so that for long loops the normal resistance of the lamps is effectively eliminated. The relay M is also provided with high resistance windings 4 and 4′, which are normally short circuited over the back contacts of said relay. The arrangement of the relay M′ with respect to the ballast lamps 13′ and 14′ is similar to that just described. When the cord circuit is used in connection with a line of considerable length the flow of current over the line is too small to operate the relay M and, consequently, the resistance of the ballast lamps is practically shunted out of circuit. When the cord circuit is connected with a line somewhat shorter, so that the current flow tends to be materially increased, the marginal relay M is energized thereby opening the short circuit about its high resistance holding windings 4 and 4′, so that the ballast lamps 13 and 14 are now shunted by paths of very high resistance and the effective resistance in both the talking circuit and the current supply circuit becomes approximately that due to the ballast lamps themselves. The resistance of these lamps increases with increase in the potential applied so that the current supplied to the sub-station is kept within reasonable limits.

A slightly modified arrangement is shown in Fig. 8. In this case the current is supplied to one end of the cord circuit through the impedance due to the initial energizing windings of marginal relays M_1 and M_2, the current being supplied to the other end of the cord circuit through the similar windings of marginal relays M_1' and M_2'. Ballast lamps 13 and 14 and 13′ and 14′ are included in the battery supply leads but are normally short circuited over the back contacts of relays M_1, M_2, M_1' and M_2', respectively. When the cord circuit is used in connection with long lines, therefore, the impedance of the ballast lamps is ineffective since the ballast lamps are short circuited. Upon somewhat shorter lines, however, the increase in current supply is sufficient to energize the marginal relays M_1 and M_2 through their initial energizing windings, thereby opening the short circuits about ballast lamps 13 and 14 and closing locking circuits for the relays M_1 and M_2 through their locking windings. Both the battery supply and talking current must now pass through a circuit including the impedance of the ballast lamps and the resistance due to the two windings of the marginal relays in parallel. The tendency of the current to increase as the loops become shorter results in an increased resistance of the ballast lamps so that both the current supply and the transmission of alternating talking current are maintained within reasonable limits.

By means of the arrangements above disclosed, simple and effective means are provided for automatically equalizing the transmission over subscribers' lines of different lengths. It will also be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, impedances in said link circuit, means to substantially equalize the transmission over all of the lines with which the link circuit may be associated, said means comprising relays responsive in accordance with the electrical characteristics of different transmission lines, and means operated by said relays to vary the impedance of said link circuit in accordance with the electrical characteristics of different transmission lines to which the link circuit is connected.

2. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, a source of direct current supply associated with said link circuit, means for substantially equalizing the transmission over all of the lines with which the link circuit may be associated, said means comprising impedances in said link circuit, relays operating in accordance with the electrical characteristics of different transmission lines, and means controlled by said relays to vary the impendances of said link circuit with respect to both direct and alternating currents in accordance with the electrical characteristics of different transmission lines with which the link circuit is connected.

3. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, impedances in said link circuit, and relays responsive to current flow over said lines to increase the impedance of said link circuit as the current flow over the lines with which it is connected tends to increase so that the transmission will be substantially equalized over all of the lines with which the link circuit may be associated.

4. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, a source of direct current supply associated with said link circuit, impedances in said link circuit, and relays responsive to current flow over said lines from said source to increase the impedance of said link circuit as the current flow over the lines with which it is connected tends to increase so that the transmission will be substantially equalized over all of the lines with which the link circuit may be associated.

5. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, a source of current associated therewith, normally shunted impedance elements in said link circuit and means responsive to an increase in the current flow from said source to remove the shunts from said impedance elements so that the transmission will be substantially equalized over all of the lines with which the link circuit may be associated.

6. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, a source of current associated therewith, normally shunted impedance elements in said link circuit and relays responsive to an increase in the current flow from said source to remove the shunts from said impedance elements so that the transmission will be substantially equalized over all of the lines with which the link circuit may be associated.

7. The combination of a plurality of transmission lines having different electrical characteristics, a link circuit for interconnecting said lines, a source of current associated therewith, normally shunted ballast lamps in said link circuit, and means responsive to an increase in the current flow from said source to remove the shunts from said ballast lamps.

8. The combination of a plurality of transmission lines having different electrical

characteristics, a link circuit for interconnecting said lines, a source of current associated therewith, normally shunted ballast lamps in said link circuit, and relays responsive to an increase in the current flow from said source to remove the shunts from said ballast lamps.

9. In a telephone system, subscribers' lines of differing electrical characteristics, substation sets for each line, a connecting means for establishing connections with said lines, and relay means in said connecting means responsive to variations in said electrical characteristics for rendering the transmission over the talking circuits of said lines substantially the same.

10. In a telephone system, subscribers' lines of differing electrical characteristics, substation sets for each line, a connecting means responsive to variations in said electrical characteristics for establishing connections with said lines, a source in said connecting means for supplying talking current for said lines, and relay means in said connecting means for rendering the flow of current from said source over said lines substantially the same.

11. In a telephone system, subscribers' lines of differing electrical characteristics, a connecting means for establishing connections with said lines, and relay means in said connecting means responsive to variations in said electrical characteristics for rendering the transmission characteristics of said lines substantially the same.

12. In a telephone system, subscribers' lines of differing electrical characteristics, a connecting circuit for establishing connections with said lines, a variable resistance included in series in the talking circuit of said connecting circuit, and means in said connecting circuit responsive to variations in said electrical characteristics for controlling said variable resistance.

In testimony whereof, I have signed my name to this specification this 19th day of October, 1918.

GEORGE K. THOMPSON.