A. B. CLARK.

MEANS FOR AND METHOD OF REGULATING THE TRANSMISSION OVER ELECTRIC CIRCUITS.

APPLICATION FILED SEPT. 10, 1918.

1,438,217.

Patented Dec. 12, 1922.

3 SHEETS—SHEET 1.

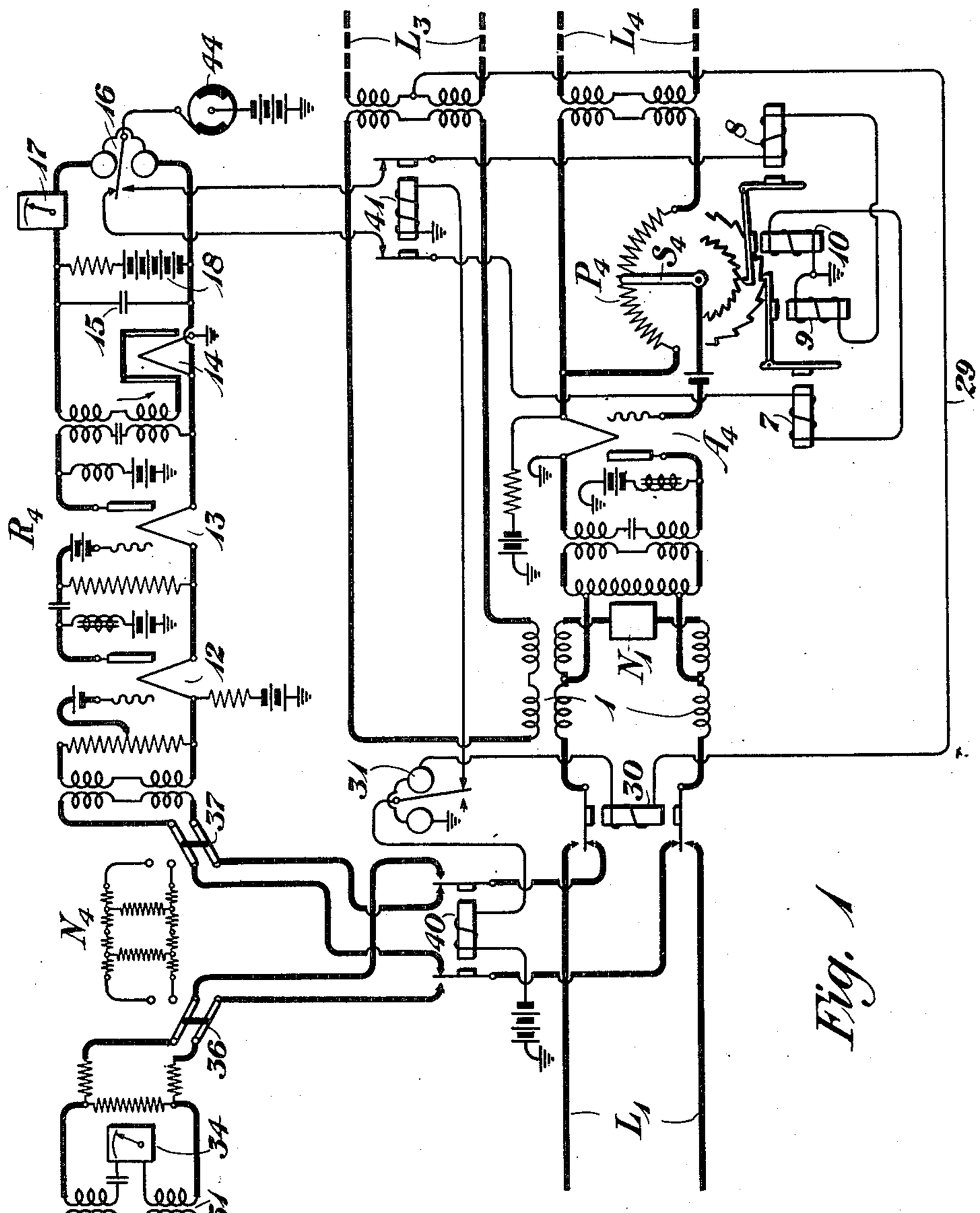

Fig. 1

INVENTOR.

A. B. Clark

BY G. E. Folk,

ATTORNEY

A. B. CLARK.

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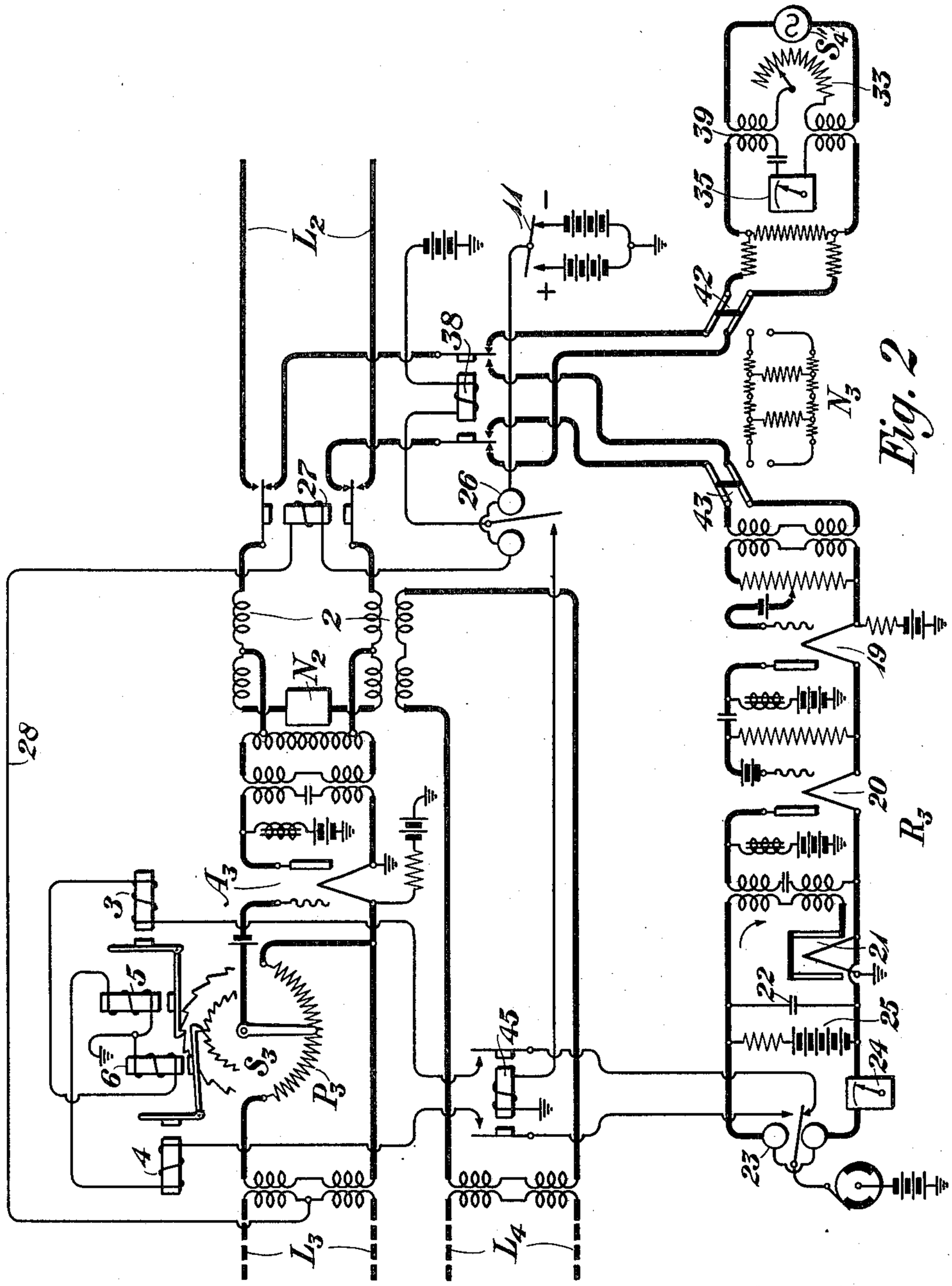

Fig. 2

INVENTOR.
A. B. Clark
BY G. E. Folk,
ATTORNEY

A. B. CLARK.

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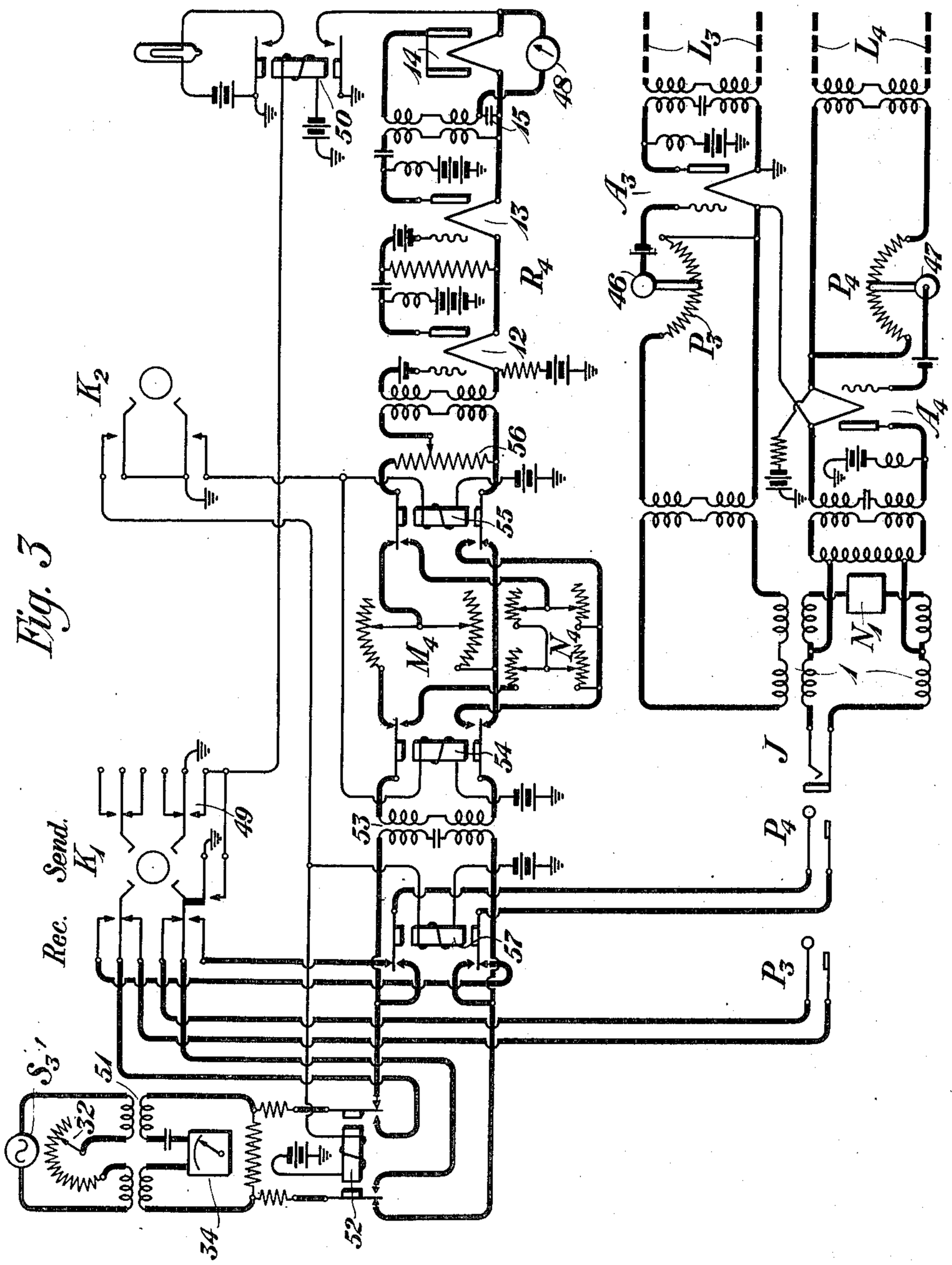
3 SHEETS—SHEET 3.

Fig. 3



INVENTOR.

A. B. Clark

BY G. E. Folk,

ATTORNEY

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UNITED STATES PATENT OFFICE.

ALVA B. CLARK, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR AND METHOD OF REGULATING THE TRANSMISSION OVER ELECTRIC CIRCUITS.

Application filed September 10, 1918. Serial No. 253,484.

To all whom it may concern:

Be it known that I, ALVA B. CLARK, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Means for and Methods of Regulating the Transmission over Electric Circuits, of which the following is a specification.

This invention relates to transmission circuits, and more particularly to transmission circuits of the type known as four-wire circuits, although it is in general applicable to transmission circuits of any kind.

The principal object of the invention is to provide suitable methods and means for maintaining constant the transmission equivalent of a circuit regardless of variations in the conditions affecting the electrical characteristics of the circuit. Other and further objects will, however, be clear from the description of the invention hereinafter given.

In general, the transmission equivalent of a circuit varies, due to a number of different causes. If the transmission circuit be of the four-wire type, in which a pair of separate transmission lines are employed for transmitting in opposite directions, these causes may be divided into two classes: The first class comprises causes which affect both sides of the circuit; or in other words both transmission lines, in the same manner. Among these causes may be enumerated variations in the resistance of the conductors, loading coils etc., variations in capacity, inductance, or other electrical characteristics of the cable, and variations in the potential of repeater batteries common to repeaters in both sides of the circuit. The second class comprises causes which affect the two sides differently, such as variations in the structure of repeater bulbs where vacuum tube repeaters are employed, variations in the potentials of grid batteries, or accidental variations due to the resistance of bad joints, leakage due to poor insulation etc.

In the case of transmission circuits in which only one transmission line is used for transmission in the two directions, the factor of variation with respect to the two sides of the circuit will be absent, but some or all of the above causes may contribute to produce variations in the transmission equivalent of the circuit, thereby rendering it highly desirable that some provision be made for overcoming the effect of these variations.

The present invention contemplates overcoming these difficulties by varying some adjustable element of the transmission circuit to compensate for the variations introduced into the circuit by any or all of the above causes. In general, a number of methods may be employed in carrying out the objects of this invention; for example the effects due to some one cause such as temperature variations, may be compensated for by observing the changes produced in one circuit of a cable, and then varying in accordance with such changes, similar elements of a number of circuits which are affected in a like manner. In the case of a four-wire circuit, effects due to all possible variations in the two sides of the four-wire circuit may be compensated for by varying like elements in the two sides of the circuit on the assumption that the two sides vary alike. If greater precision is desired, the adjustment may be made for each side of the four-wire circuit separately to compensate for all causes of variation in either side.

These methods may be carried out either manually or automatically, and by making adjustments either constantly as the circuit varies, or at intervals of suitable frequency. For purposes of illustration, apparatus is disclosed for carrying out the last method above mentioned either manually or automatically, but it will be understood that any of the above mentioned methods are within the scope of this invention.

The objects of the invention are secured as herein disclosed by impressing potential variations of known characteristics upon a suitable receiving apparatus through a transmission element having a transmission equivalent equal to that to which it is desired that the circuit shall be adjusted. The receiving apparatus is then so arranged that a desired effect is produced thereon. Similar potential variations are then transmitted over the circuit to be regulated, and impressed upon the receiving apparatus. Some element of the circuit, such as an am-

plifier, is then adjusted either manually or automatically under the control of the receiving apparatus until the same effect is produced on the receiving apparatus as in the first case. By separately treating both sides of the four-wire circuit in this manner, the circuit may be so altered that its transmission equivalent is the same in either direction regardless of the causes producing variations in its electrical characteristics.

The invention may now be more fully understood by reference to the following description when read in connection with the accompanying drawing in which Figures 1 and 2, when placed end to end, constitute a circuit diagram of an arrangement for automatically adjusting a four-wire transmission circuit to a desired transmission equivalent, while Fig. 3 illustrates a somewhat similar arrangement for securing the same result manually.

Referring to Figs. 1 and 2, two distant stations are shown interconnected by a four-wire circuit comprising transmission line L_3 for transmitting in one direction, and transmission line L_4 for transmitting in the opposite direction. The terminating apparatus at one station is shown in Fig. 1, and that of the other station is shown in Fig. 2. It will be understood that each of the transmission lines L_3 and L_4 may include one or more one way repeaters (not shown) located at intermediate stations. At the terminating stations, the four-wire circuit is associated by means of the usual three-winding transformers 1 and 2, with terminating two-wire lines L_1 and L_2, said terminating two-wire lines being balanced by suitable artificial lines N_1 and N_2. In order to adjust the transmission equivalent of the four-wire circuit, amplifiers A_3 and A_4 are inserted in the lines L_3 and L_4 respectively at the terminal stations. These amplifiers as illustrated are of the vacuum tube type, but it will be understood that any type of amplifier, or in fact, any type of adjustable transmission device capable of giving either a loss or a gain may be employed for this purpose. The employment of an amplifier for this purpose, however, has the advantage that it may serve to secure or assist in securing the desired amplification for the four-wire circuit as well as for adjusting the transmission equivalent of the circuit. In order to vary the amplification of the amplifiers A_3 and A_4 potentiometers P_3 and P_4 are provided in the grid circuits of the amplifiers. In order to vary the setting of the potentiometer P_3, an automatic switch S_3 is provided, said switch being adapted to be rotated in either of two directions under the control of stepping magnets 3 or 4; release magnets 5 and 6 being provided to hold the switch in its altered position. A similar switch S_4 is provided for potentiometer P_4, said switch being controlled by stepping magnets 7 and 8, and release magnets 9 and 10.

In order to regulate the transmission equivalent of the four-wire circuit, a switch 11 is provided, as shown in Fig. 2, said switch controlling a simplex circuit over the two sides of line L_3 of the four-wire circuit or controlling any other suitable circuit between the terminals of the four-wire circuit to disconnect the four-wire circuit from the terminating two-wire lines L_1 and L_2 and connect it to the transmission adjusting apparatus. The transmission adjusting apparatus at the station of Fig. 1 comprises a source of potential variations S_3' and a receiving apparatus R_4. A similar source of potential variations S_4' and receiving apparatus R_3 is also provided at the station of Fig. 2. The two sources should have similar electrical characteristics, and in order to calibrate the receiving apparatus, for instance, receiving apparatus R_4, the source S_3' may be connected to the receiving apparatus R_4 through a network or transmission element N_4 whose transmission equivalent is equal to that to which it is desired to adjust each side of the four-wire circuit. N_4 may consist of an amplifier when it is desired to adjust the transmission equivalent of the four-wire circuit to a value less than zero (i. e. a gain). The receiving apparatus comprises amplifiers 12 and 13 and a vacuum tube rectifier 14, said rectifier being shunted by a condenser 15 and a polarized relay 16. If desired, an ammeter 17 may be included in circuit with the polarized relay 16. Alternating current impressed upon the receiving apparatus will be amplified by amplifiers 12 and 13 and rectified by rectifier 14 so that current will only flow through the rectifier in the direction indicated by the arrow. A battery 18 is connected in shunt of the rectifier 14 and so poled as to tend to cause a current flow through the polarized relay 16 in a direction opposite to that which flows from the rectifier 14 through the polarized relay. The alternating current from the source S_3' is transmitted through the network N_4 to the receiving apparatus R_4 and the amplifiers 12 and 13 are adjusted so that the rectified current passing through the polarized relay 16 from rectifier 14 is just equal to that from the battery 18, so that no effect is produced on the polarized relay 16. Circuits are arranged whereby the polarized relay 16 may control the setting of the switch S_4. In a similar manner the receiving apparatus R_3 at the station of Fig. 2 may comprise amplifiers 19, 20, rectifier 21 shunted by condenser 22, polarized relay 23, ammeter 24 and battery 25, these elements being similar in all respects to the

corresponding elements of Fig. 1. The polarized relay 23 controls circuits for stepping the switch S_3.

Suitable switching arrangements are provided at the two terminating stations so that when the receiving arrangements have been calibrated, the source of potential variations at one station may be connected to the four-wire circuit, transmitted thereover in one direction, and applied to the corresponding receiving apparatus at the other station. Should the transmission equivalent of the circuit for transmission in that direction be above or below that of the network N_4 or its corresponding network N_3, current will flow through the polarized relay of the receiving apparatus to throw its armature in one direction or the other, thereby causing the automatic switch to adjust the potentiometer until current no longer flows through the polarized relay, the transmission equivalent being then equal to that of the network N_3 or N_4 as the case may be.

Assuming that it is desired to regulate the transmission equivalent for transmission from the station at Fig. 2, to the station at Fig. 1 over the line L_4, the sources of potential variations S_3' and S_4' are first adjusted by means of the rheostats 32 and 33 so that potential variations of the same characteristics are supplied by each as measured by the alternating current ammeters 34 and 35. Switches 36 and 37 are so thrown as to connect the source S_3' to the receiving apparatus R_4 through the network N_4. By adjusting the potentiometer of the amplifier 12, the receiving apparatus may be so calibrated that no current flows through the polarized relay 16, whose armature will consequently be in a neutral position. Switches 36 and 37 are then restored to the position shown in the diagram, and the switch 11 is thrown so as to connect negative battery to the simplex circuit over the transmission line L_3. Current then flows from negative battery over the switch 11 through polarized relay 26, relay 27, conductor 28, thence in parallel over the two sides of line L_3, over conductor 29, through relay 30, polarized relay 31 to ground. Relays 27 and 30, as well as polarized relay 31, are actuated by the current flowing in this circuit, but the direction of the current is such that polarized relay 26 is unactuated. The relay 27 disconnects the four-wire circuit from the terminating line L_2 at the station of Fig. 2 and connects the four-wire circuit to the source S_4' over the front contacts of relay 27, back contacts of relay 38, contacts of switch 42 to the winding of transformer 39, through which current is transmitted from the source S_4' to the four-wire circuit. At the station of Fig. 1 the actuation of the polarized relay 31 completes a circuit from battery, through the winding of relay 40, over the contact of relay 31, through the winding of relay 41 to ground. The actuation of relay 41 completes circuits over its front contacts from the opposite contacts of polarized relay 16 through the stepping magnets and release magnets of the switch S_4. By the energization of relays 30 and 40, the four-wire circuit is disconnected from the two-wire line L_1, and is connected over the front contacts of relay 30, front contacts of relay 40, and contacts of switch 37 to the receiving apparatus R_4. Alternating current is now transmitted from the source S_4' through the three-winding transformer 2, over transmission line L_4, through the amplifier A_4, over the front contacts of relays 30 and 40, the contacts of switch 37 to the receiving apparatus R_4. The current thus transmitted is amplified by amplifiers 12 and 13, and rectified by rectifier 14. If the transmission over the circuit L_4 is too low, current will flow through the polarized relay 16 in such a direction as to throw the armature of said relay to its upper position whereupon current flows from battery, through the interrupter 44, which may be of any well-known type, such as a rotating commutator, upper contact of polarized relay 16, left-hand front contact of relay 41, winding of stepping magnet 7 and winding of release magnet 10 to ground. Each pulse of current through the circuit just traced causes the release magnet 10 to withdraw the pawl carried by the armature of stepping magnet 8 from the corresponding ratchet wheel and causes the stepping magnet 7 to advance its ratchet wheel one step. The switch S_4 is thus advanced step by step until the potentiometer is so adjusted that the amplification of the amplifier A_4 brings the transmission equivalent of the circuit up to a point where it is equal to that of the network N_4. When this condition is reached, current no longer flows through the polarized relay 16, and the desired adjustment for the transmission line L_4 is attained. Should the transmission over the line L_4 be too great, current will flow through the polarized relay 16 in the opposite direction, thereby throwing its armature to its lowest position and actuating stepping magnet 8 and release magnet 9 to step the switch S_4 in the opposite direction until the proper transmission equivalent is obtained.

In order to regulate the transmission over the line L_3 in the opposite direction, the receiving apparatus R_3 will first be calibrated in a manner similar to that already described, and the switch 11 will then be thrown to connect positive battery to the simplex circuit through polarized relay 26, relays 27 and 30, and polarized relay 31. The current flowing through this circuit is now in the opposite direction, so that the relays 27 and 30 are actuated as before, and

polarized relay 26 is operated instead of polarized relay 31. The operation of polarized relay 26 completes a circuit for relays 38 and 45, so that the receiving apparatus R_3 is connected to the four-wire circuit and the circuits of the stepping and holding magnets of the switch S_3 are connected to the contacts of the polarized relay 23. At the station at Fig. 1, the source S_3' is connected to the four-wire circuit and transmission now takes place over the line L_3. The operation is now in all respects similar to that already described for the transmission line L_4 and no further description is necessary. Upon restoring the switch 11 to neutral position, thereby opening the simplex circuit, the four-wire circuit will be again connected to the terminating two-wire lines L_1 and L_2.

Instead of arranging the apparatus so that the adjustment of the four-wire circuit is performed automatically a manual apparatus such as illustrated in Fig. 3 may be employed. In this figure the apparatus shown at one terminal station only of the four-wire circuit is illustrated, it being understood that similar apparatus will be provided at the opposite terminal station. The four-wire circuit comprising transmission lines L_3 and L_4 is related through the usual three-winding transformer 1 to a two-wire extension terminating in a jack J, whereby connections may be made to two-wire lines. For adjusting the transmission equivalent of the circuit amplifiers A_3 and A_4 are associated with transmission lines L_3 and L_4 respectively, and potentiometers P_3 and P_4 are provided for the purpose of adjusting the amplification of the amplifiers. The setting of the potentiometers may be controlled by manual switches 46 and 47. The amplifier A_3, and its potentiometer P_3 are shown at the same station as amplifier A_4 and potentiometer P_4, but it will be understood that these devices may be arranged at the other terminating station, as shown in connection with the automatic arrangement of Fig. 2. A source of potential variations similar in all respects to that shown in Fig. 1 is provided, a plug P_3 adapted to cooperate with the jack J being employed for associating the source with the four-wire circuit. A receiving apparatus R_4 similar to that shown in Fig. 1 may be associated with the four-wire circuit by means of a plug P_4 adapted to cooperate with the jack J. The receiving apparatus R_4 differs from that of Fig. 1 in that no polarized relay is provided, but instead, an indicating arrangement such as the indicating meter 48 is associated with the rectifier 14. Transmission elements M_4 and N_4 are provided for purposes more fully hereinafter apparent. For controlling the various connections, keys K_1 and K_2 are shown. When the key K_2 is operated with the key K_1 in its normal position, the source of potential variations S_3 may be connected to the four-wire circuit through the plug P_3. With the key K_2 operated and the key K_1 thrown to the left, the source S_3' is disconnected from the plug P_3 and the receiving apparatus R_4 may be connected with the four-wire circuit through the plug P_4. With the key K_2 unactuated and the key K_1 thrown to the right, the source S_3' may be applied to the receiving apparatus R_4 through the transmission device M_4 for purposes of calibration.

In order to calibrate a receiving apparatus, the transmission arrangement M_4 will be given some arbitrary setting as previous experience or the exigencies of the particular situation may determine. The key K_1 is then thrown to the right, thereby closing a circuit over its contact 49 and through relay 50 to battery. Relay 50, upon being energized, at its lower front contact completes the series filament circuits of amplifiers 12 and 13 and rectifier 14, thereby rendering the receiving apparatus operative. The source S_3 is now connected to the receiving apparatus R_4 through the transformer 51, back contacts of relay 52, transformer 53, back contacts of relay 54, through the transmission device M_4, and back contacts of relay 55. The potentiometer 56 of amplifier 12 may now be adjusted so as to give a proper reading of the indicating meter 48.

If now it is desired to regulate the transmisison equivalent of the transmission line L_4, the key K_2 at the station shown is operated, the key K_1 is thrown to the left and the plug P_4 is inserted in the jack J. The actuation of key K_2 completes energizing circuits for relays 54 and 55 over its lower contact and completes enerigzing circuits for relays 52 and 57 over its upper contact. Relays 54 and 55 disconnect the transformer 53 and receiving apparatus R_4 from the transmission device M_4 and connect them to the transmission device N_4. Relay 52 connects the source S_3' over its front contacts to the left hand contacts of key K_1, while relay 57, over its front contacts, connects the transformer 53 to the plug P_4. The actuation of the key K_1 disconects the source S_3' from the plug P_3. The receiving apparatus R_4 is now connected to the four-wire circuit over the front contacts of relay 55 through the transmission device N_4, front contacts of relay 54, transformer 53, front contacts of relay 57, plug P_4 and jack J.

At the opposite terminal station a source similar to S_3 is associated with the four-wire circuit by operating the key corresponding to K_2 leaving the key corresponding to K_1 in its normal postion. The source corresponding to S_3' will then be connected to the four-wire circuit through the transformer corresponding to 51 over the

front contacts of a relay corresponding to 52, over the normal left hand contacts of the key corresponding to K_1 and over the contacts of the plug corresponding to P_3 and the terminating jack of the four-wire circuit at the opposite terminal station. Potential variations are then transmitted from the source corresponding to S_3' over the transmission line L_4 through the amplifier A_4, and thence over jack J and the plug P_4 and the circuit previously traced, to the receiving apparatus R_4. The transmission device N_4 is now set so that its transmission equivalent will be equal to the algebraic difference between the transmission equivalent of the device M_4 and the desired transmission equivalent for the transmission line L_4. By operating the switch 47 the potentiometer P_4 may be adjusted until the indicating meter 48 gives the same indication as when it was calibrated. Under this condition, the transmission line L_4 will have a transmission equivalent equal to the difference between the transmission equivalents of transmission devices M_4 and N_4.

If, instead of regulating the transmission of the transmission line L_4 it is desired to determine its actual transmission equivalent, the circuits may be arranged as just described and the adjustable transmission device N_4 adjusted until the same indication is given by the ammeter 48 as when it was calibrated. The device may be provided with a scale so that under this condition the transmission equivalent of the transmission circuit may be read directly in terms of some suitable unit.

When it is desired to determine the transmission equivalent, or to regulate the transmission of the circuit of the line L_3 the apparatus of Fig. 3 will be so set as to connect the source S_3' to the four-wire circuit over plug P_3 and jack J, while at the opposite terminal station the apparatus will be arranged to connect the receiving apparatus to the four-wire circuit. Since the operation is in all respects similar to that already discussed, no further discussion thereof is deemed necessary.

It will be apparent that by means of the apparatus and methods herein disclosed, the transmission equivalent of a circuit may be maintained constant at any desired value, regardless of variations due to any cause whatever. 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 method of adjusting the efficiency of a transmission line extending between two signaling stations, which consists in applying potential variations of known characteristics upon a receiving apparatus through a transmission element, adjusting the circuit including said transmission element and said receiving apparatus until a desired effect is produced upon the receiving apparatus, impressing potential variations of similar characteristics upon said receiving apparatus through said transmission line, and adjusting an element of the transmission line until the same effect is produced upon the receiving apparatus.

2. The method of adjusting the efficiency of a transmission line including amplifying means, which consists in applying potential variations of known characteristics upon a receiving apparatus through a transmission element, adjusting the circuit including said transmission element and said receiving apparatus until a desired effect is produced upon the receiving apparatus, impressing potential variations of similar characteristics upon said receiving apparatus through said transmission line, and adjusting the amplification of said amplifying means until the same effect is produced upon the receiving apparatus.

3. The method of adjusting the efficiency of a transmission line extending between two signaling stations, which consists in applying potential variations of known characteristics upon a receiving apparatus through a transmission element having a transmission equivalent equal to that to which it is desired to adjust the transmission line, impressing potential variations of similar characteristics upon said receiving apparatus through said transmission line, and adjusting an element of the transmission line until the same effect is produced upon the receiving apparatus.

4. The method of adjusting the efficiency of a transmission line including amplifying means, which consists in applying potential variations of known characteristics upon a receiving apparatus through transmission element having a transmission equivalent equal to that to which it is desired to adjust the transmission line, impressing potential variations of similar characteristics upon said receiving apparatus through said transmission line, and adjusting the amplification of said amplifying means until the same effect is produced upon the receiving apparatus.

5. The method of adjusting the efficiency of the two sides of a four-wire circuit including a pair of transmission lines for transmitting in opposite directions, which consists in calibrating separate sets of receiving apparatus adapted to be associated with said transmission lines, so that a desired effect will be produced upon each receiving apparatus when similar potential

variations of known characteristics are impressed thereupon through a transmission path having a desired transmission equivalent, separately impressing potential variations having the desired characteristics upon each receiving apparatus through the corresponding transmission line, and adjusting elements of the transmission lines until the desired effect is produced in the receiving apparatus.

6. In a signaling system, a transmission line, a receiving apparatus, means to apply potential variations of known characteristics upon said receiving apparatus through a transmission element having a desired transmission equivalent thereby producing a desired effect upon the receiving apparatus, means to associate the receiving apparatus with one end of said line, means to apply potential variations of similar characteristics to the other end of said line, and means to adjust the transmission equivalent of said line until the desired effect is produced upon the receiving apparatus.

7. In a signaling system, a transmission line, a receiving apparatus, a transmission element having a desired transmission equivalent, means to associate said receiving apparatus with said transmission element, means to apply potential variations of known characteristics upon said receiving apparatus through said transmission element, means to associate said receiving apparatus with one end of said line, means to apply potential variations of similar characteristics to the other end of said line, and means to adjust the transmission equivalent of the line until the same effect is produced upon the receiving apparatus as when potential variations were impressed thereupon through said transmission element.

8. In a signaling system, two stations, a transmission line interconnecting said stations, similar sources of potential variations at each station, receiving apparatus at one of said stations, a transmission element having a desired transmission equivalent at said station, means to apply the source of potential variations at said station upon said receiving apparatus through said transmission element, means to apply the source of potential variations at the other station upon said receiving apparatus through said transmission line, and means to adjust the transmission equivalent of said line until the same effect is produced upon the receiving apparatus under the latter condition as was produced under the first condition.

9. In a signaling system, two stations, a transmission line interconnecting said stations, amplifying means for said line, similar sources of potential variations at each station, receiving apparatus at one of said stations, a transmission element having a desired transmission equivalent at said station, means to apply the source of potential variations at said station upon said receiving apparatus through said transmission element, means to apply the source of potential variations at the other station upon said receiving apparatus through said transmission line, and means to adjust the amplification of said amplifying means until the same effect is produced upon the receiving apparatus under the latter condition as was produced under the first condition.

10. In a signaling system, two stations, a transmission line interconnecting said stations, similar sources of potential variations at each station, receiving apparatus at one of said stations, a transmission element having a desired transmission equivalent at said station, means to apply the source of potential variations at said station upon said receiving apparatus through said transmission element, means to apply the source of potential variations at the other station upon said receiving apparatus through said transmission line, and means controlled by said receiving apparatus for adjusting the transmission equivalent of the line until it is equal to that of said transmission element.

11. In a signaling system, two stations, a transmission line interconnecting said station, similar sources of potential variations at each station, receiving apparatus at one of said stations, a transmission element having a desired transmission equivalent at said station, means to apply the source of potential variations at said station upon said receiving apparatus through said transmission element, means to adjust the receiving apparatus so that no effect is produced thereon when potential variations are so applied, means to apply the source of potential variations at the other station upon said receiving apparatus through said transmission line, and means responsive to the actuation of the receiving apparatus under the latter condition to adjust the transmission equivalent of the line until the receiving apparatus is unactuated.

12. In a signaling system, two stations, a transmission line interconnecting said station, amplifying means for said transmission line, similar sources of potential variations at each station, receiving apparatus at one of said stations, a transmission element having a desired transmission equivalent at said station, means to apply the source of potential variations at said station upon said receiving apparatus through said transmission element, means to adjust the receiving apparatus so that no effect is produced thereon when potential variations are so applied, means to apply the source of potential variations at the other station upon said receiving apparatus through said transmission line, and

means responsive to the actuation of the receiving apparatus under the latter condition to adjust the amplification of said amplifying means until the receiving apparatus is unactuated.

13. In a signalling system, a circuit extending between two stations for transmitting alternating currents between said stations, said transmission circuit including an adjustable transmission device, and means operating automatically under the control of a change in transmission to adjust said transmission device so that the transmission circuit will have a predetermined transmission equivalent.

In testimony whereof, I have signed my name to this specification this sixth day of September, 1918.

ALVA B. CLARK.