S. P. SHACKLETON.

MEANS FOR REGULATING THE TRANSMISSION OVER FOUR-WIRE CIRCUITS.

APPLICATION FILED SEPT. 10, 1918.

1,438,270.

Patented Dec. 12, 1922.

2 SHEETS—SHEET 1.

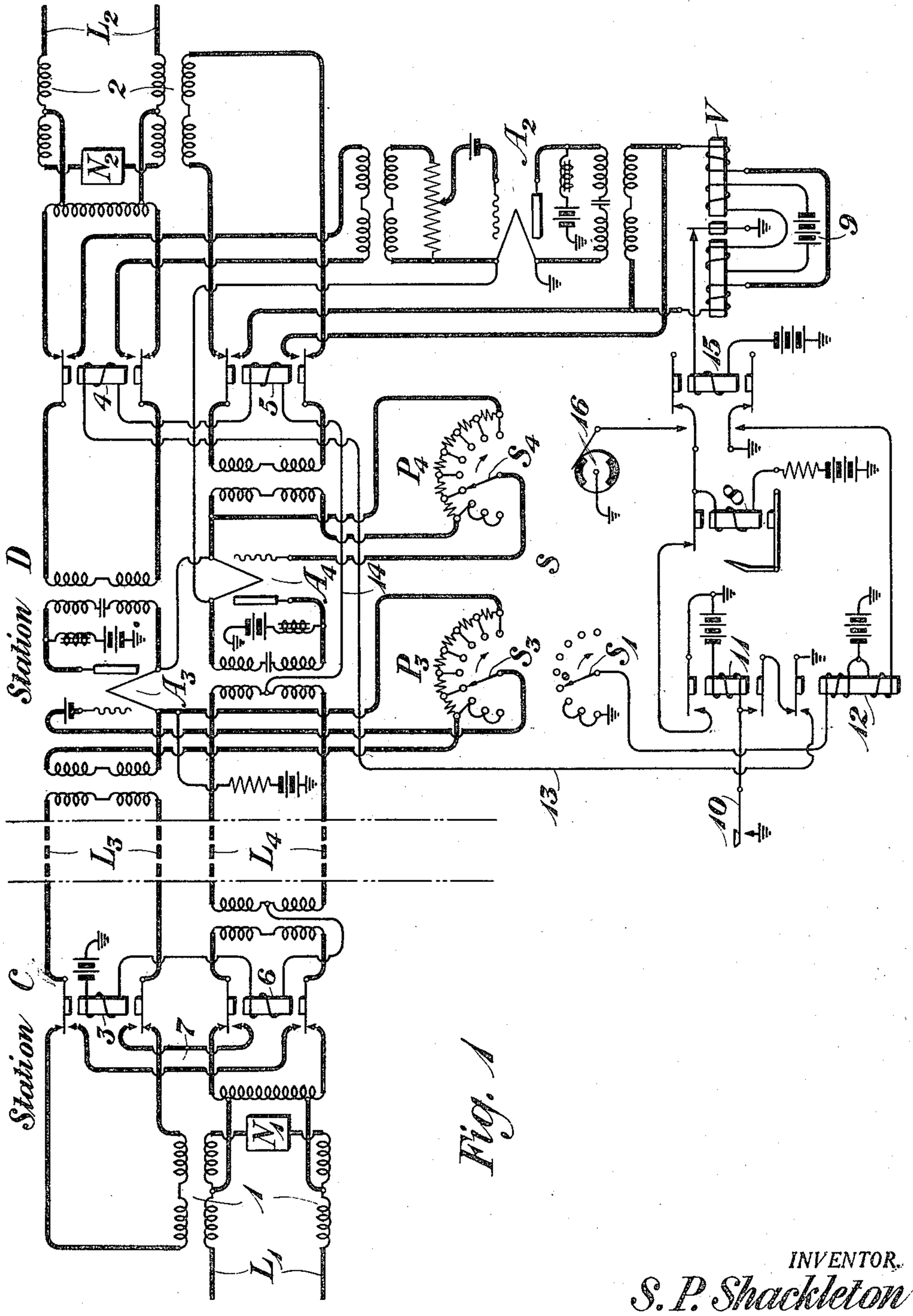

Fig. 1

INVENTOR.

S. P. Shackleton

BY G. E. Folsom

ATTORNEY

S. P. SHACKLETON.

MEANS FOR REGULATING THE TRANSMISSION OVER FOUR-WIRE CIRCUITS.

APPLICATION FILED SEPT. 10, 1918.

1,438,270.

Patented Dec. 12, 1922.

2 SHEETS—SHEET 2.

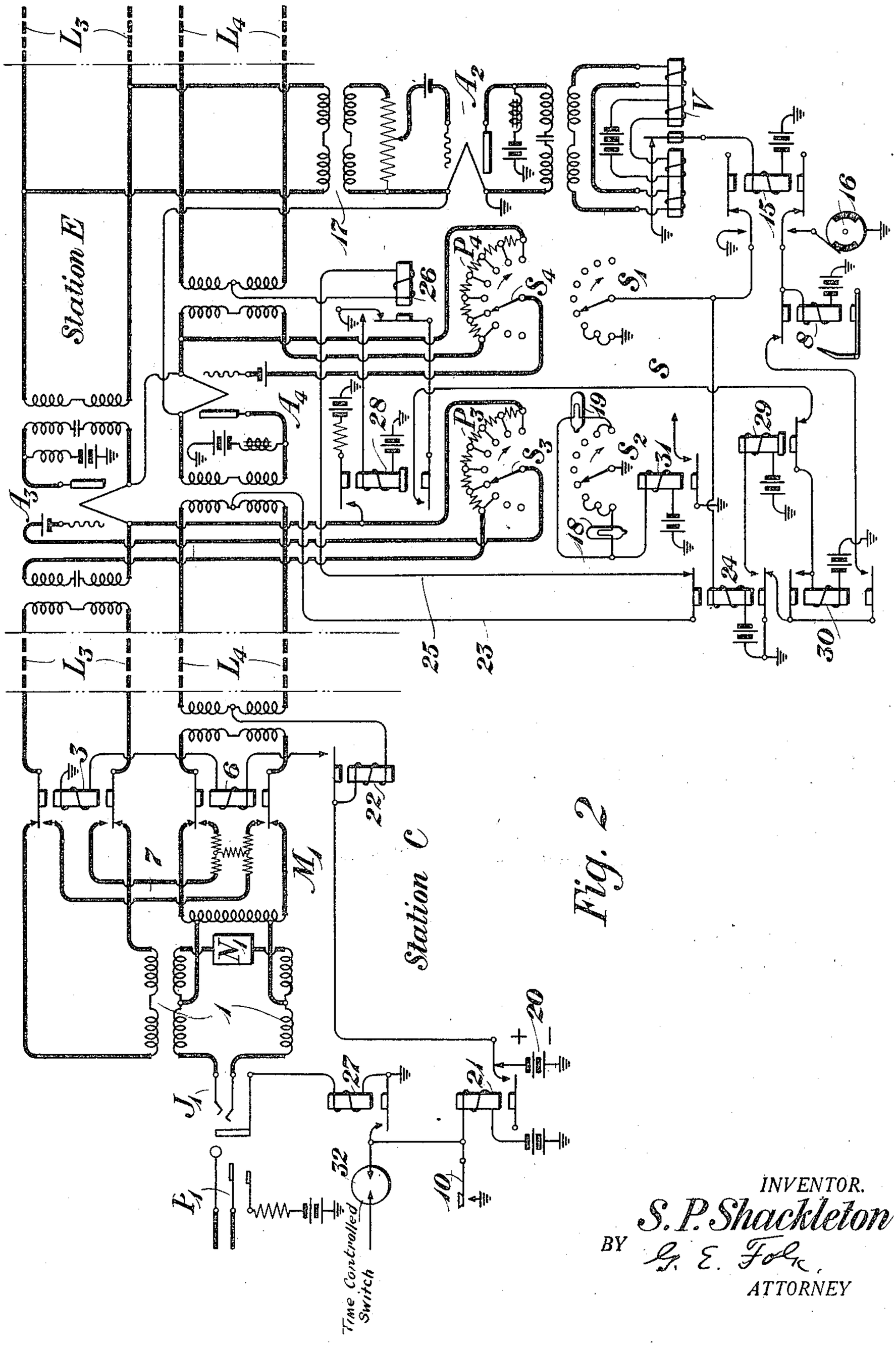

Fig. 2

INVENTOR.

S. P. Shackleton

BY G. E. Folk,

ATTORNEY

Patented Dec. 12, 1922. 1,438,270

UNITED STATES PATENT OFFICE.

SAMUEL P. SHACKLETON, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR REGULATING THE TRANSMISSION OVER FOUR-WIRE CIRCUITS.

Application filed September 10, 1918. Serial No. 253,460.

To all whom it may concern:

Be it known that I, SAMUEL P. SHACKLETON, residing at New York, in the borough of Bronx and State of New York, have invented certain Improvements in Means for Regulating the Transmission Over Four-Wire 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 type.

The principal object of the invention is to provide suitable means for maintaining the transmission equivalent of a circuit constant, 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 hereafter appearing.

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 transmission 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 resistance of the conductors or loading coils, variations in the 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 in 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 effects of these variations.

The present invention contemplates eliminating these difficulties by varying some adjustable element of the transmission circuit to compensate for variations introduced into the circuit.

The objects of the invention are secured as herein disclosed by disconnecting the ends of the two transmission lines, comprising a four-wire circuit from their terminating arrangements, and interconnecting the ends through adjustable transmission devices having a transmission equivalent double and opposite in sign to, that to which the sides of the four-wire circuit exclusive of the terminals are to be adjusted. The gain in the four-wire circuit is then increased to a maximum value, preferably by increasing the amplification of one-way repeaters in the two transmission lines of the four-wire circuit. This causes singing to take place in the four-wire circuit and by gradually decreasing the amplification of similar amplifiers in the two transmission lines until singing just ceases the four-wire circuit will be set for the desired transmission equivalent. In order to perform these functions automatically the circuit may be so arranged that when the two ends of the four-wire circuit are interconnected, an automatic switch controlling the setting of the potentiometers which determine the amplification of the repeaters, will be restored to its normal condition, thereby setting the potentiometers to permit the greatest possible amplification. Singing then takes place and an alternating current relay responsive to the singing oscillations may be arranged to control the advancing of the switch until the potentiometers are at a position such that singing just ceases.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawings, Figure 1 of which is a diagram of a circuit arrangement embodying one form of the invention, while Figure 2 is a circuit diagram of a preferred form of the invention.

Referring to Figure 1, the four-wire circuit is shown interconnecting two distant stations C and D, said four-wire circuit comprising a pair of transmission lines L_3 and L_4 for transmission in opposite directions. Normally the four-wire circuit is connected to terminating two-wire lines L_1 and L_2 at

stations C and D respectively, through the usual three-winding transformers 1 and 2. It will be understood that the transmission lines L_3 and L_4 may include one-way repeaters located either at the terminal stations, or at intermediate stations for the purpose of securing the desired amplification. In order to simplify the diagram the one-way repeaters have been omitted. Relays 3, 4, 5 and 6 are provided whereby the ends of the transmission lines L_3 and L_4 may be disconnected from the terminating arrangements and interconnected through conductors 7 at station C, and through a transmission arrangement at station D, here shown as comprising an amplifier A_2. The amplifier A_2 may be adjusted so that its transmission equivalent is opposite in sign and equal to twice that to which it is desired to have each side of the four-wire circuit, exclusive of the terminal arrangements, adjusted. In order to control the adjustment of the four-wire circuits, amplifiers A_3 and A_4 are inserted in the lines L_3 and L_4 and the amplification of these amplifiers is determined by potentiometers P_3 and P_4. The setting of the potentiometers is controlled by an automatic switch S, including wipers S_1, S_3 and S_4. This switch is capable of movement in one direction only, and may be advanced step by step under the control of a stepping magnet 8. An alternating current relay V is provided, said relay having two sets of windings, one set being bridged across the connection including the amplifier A_2 and the other set of windings being in series with a local source of current 9. A switch 10 is shown for the purpose of initiating the adjustment of the four-wire circuit, said switch being either hand operated, or else controlled by a suitable timing device. The circuits are so arranged that when the switch 10 is operated, the four-wire circuit is disconnected from the terminal arrangements and the ends of the lines L_3 and L_4 are interconnected as above described through the amplifier A_2. The switch S then automatically steps around to its initial or zero position, thereby setting the potentiometers P_3 and P_4 so that the highest degree of amplification is produced by the amplifiers A_3 and A_4 and singing takes place in the circuit. The relay V is designed to respond to singing oscillations and the switch again begins to advance under the control of this relay until singing just ceases, when the relay no longer responds, and the switch remains in its advanced position with the potentiometer so set that each side of the four-wire circuit, aside from its terminating arrangements, has a transmission equivalent opposite in sign and equal to one-half that of the amplifier A_2.

Upon operating the switch 10, a circuit is completed through the winding of relay 11, which is thereby energized and is locked up over a circuit from ground, back contact of the armature of relay 12, lower front contact of relay 11, and through the winding of said relay to battery. At its upper front contact relay 11 closes an interrupted circuit from ground over said contact, over the back contact of stepping magnet 8 and through the winding of said magnet to battery. The stepping magnet 8 now intermittently interrupts its own circuit, and under the control of relay 11 drives the switch S in the direction of the arrows until the wiper S_1 encounters a grounded contact. A circuit is now closed from ground over the wiper S_1 and through the upper winding of relay 12 to battery. Relay 12 is now energized and by attracting its armature, opens the locking circuit of the relay 11, which is restored to normal, thereby opening the self-interrupting circuit of stepping magnet 8 and stopping the rotation of switch S. Relay 12 at its front contact closes a circuit from ground, over the conductor 13, through the windings of relays 4 and 5, over conductor 14, over the two sides of the line L_4 in parallel, and thence through the windings of relays 6 and 3 to battery. The energization of relays 3, 4, 5 and 6 disconnects the ends of the transmission lines L_3 and L_4 from the terminating arrangements and interconnects them through conductors 7, and through the amplifier A_2.

The wiper S_1 of the switch S encounters a grounded contact at a position of the switch such that the wipers S_3 and S_4 are connected to the extreme left hand contacts of the potentiometers P_3 and P_4. With this setting of the potentiometers, amplifiers A_3 and A_4 produce the highest degree of amplification, and singing takes place in the circuit. The relay V now responds in a well known manner to the singing oscillations and opens the normally closed circuit of relay 15. At its lower back contact, relay 15 now closes a locking circuit through the lower winding of the relay 12, so that the relays 3, 4, 5 and 6 are maintained in energized condition. At its upper back contact relay 15 closes a circuit from ground, through the interrupter 16, and through the winding of the stepping magnet 8 to battery. It will be seen that this circuit is independent of the self-interrupting circuit previously traced for the stepping magnet 8, so that the stepping magnet now advances the switch S under the control of the interrupter 16. As the wipers S_3 and S_4 of the switch in advancing vary the setting of the potentiometer, the amplification of amplifiers A_3 and A_4 is gradually reduced until singing just ceases, whereupon the relay V, being no longer actuated, permits the circuit of relay 15 to be again closed. Relay

15 opens the circuit of stepping magnet 8 at its upper front contact, and stops the switch, while at its lower contact it opens the locking circuit through the lower winding of relay 12. In the meantime, the wiper of switch S has been advanced to an ungrounded contact so that the circuit through the upper winding of the relay 12 is open and said relay is de-energized, thereby opening the circuit through relays 3, 4, 5 and 6. The de-energization of these relays restores the four-wire circuit to its normal talking condition, and the potentiometers remain set in their adjusted position so that if the amplifier A_2 has been properly calibrated, the four-wire circuit will have the desired transmission equivalent.

A somewhat more refined arrangement is illustrated in Figure 2. This arrangement differs from that of Figure 1 in that the amplifiers A_3 and A_4, with the associated potentiometers and the switch S, are located at an intermediate station E, instead of at a terminating station. The apparatus at the terminating station D is not shown, but is quite similar to that shown for station C. At the station C the ends of the lines L_3 and L_4 may be disconnected from the terminal arrangements, and connected through conductors 7, which may include a transmission arrangement M_1. In a similar manner the ends of the transmission lines L_3 and L_4 at station D (not shown) may be disconnected from the terminal arrangements, and connected through a similar transmission device. In either case, the transmission equivalent of these devices should be equal to, but opposite in sign to, that desired for the four-wire circuit. At station C the four-wire circuit is associated by means of a transformer 1 with a jack J_1 adapted to cooperate with a plug P_1, whereby it may be connected to a terminating two-wire line. A similar arrangement will be provided at the other terminal station. The amplifier A_2 in this form of the invention is not used to determine the transmission equivalent of the four-wire circuit, since it is simply bridged across one of the transmission lines of the four-wire circuit through a transformer 17 at the intermediate station E. The impedance of the bridge through transformer 17 should be very high, so that no appreciable transmission loss is involved by this connection. The switch S may be provided with an additional wiper for controlling signal lamps 18 and 19, when the setting of the potentiometer indicates an abnormal condition of the circuit.

Normally a circuit is completed from the positive pole of the battery 20 over the back contact of relay 21, through the winding of relay 22, over the two sides of the line L_4, and thence over a conductor 23, upper normal contact of relay 24, conductor 25, through the winding of relay 26, and thence in parallel over the two sides of the transmission line L_4 to station D (not shown), whence the circuit will continue through a relay corresponding to relay 22 at that station to the negative pole of a battery similar to battery 20 located at that station. The relays 22 and 26, and the relay corresponding to 22 at station D are energized over this circuit, the relay 22 thereby maintaining the circuit of relays 3 and 6 open. The circuit of similar relays at station D is maintained in the same condition. When, however, the plug P_1 is inserted in the jack J_1 in completing a connection to a terminating two-wire line, the sleeve relay 27 is energized and completes a circuit for the relay 21. The relay 21 disconnects positive battery 20 from the simplex circuit through relays 22, 26 and the corresponding relay at station D, so that these relays are de-energized. Similarly when the plug at station D corresponding to plug P_1 is inserted in the jack at that station the sleeve relay is energized to de-energize the relay corresponding to relay 21 and disconnect the negative battery. Thus it will be noted that the insertion of the plug at either station will result in the de-energization of relays 22, 26 and relay at station D, corresponding to 22. Similarly relays at other intermediate stations corresponding to relay 26 will be deenergized. It will be noted that when the relay 22 is de-energized a circuit will be completed from ground through the windings of relays 3 and 6, over the back contact of relay 22, through the winding of said relay and over the simplex circuit previously traced to the negative battery at station D. The resistance of the line L_4 is so great, however, that relays 22, 26 and the corresponding relay at station D are only energized when both Morse batteries are connected in series. Relays 3 and 6 are also unenergized at this time due to the resistance of the line. As soon as relay 26 at station E is de-energized, a circuit is completed from ground over its back contact and through the winding of the slow releasing relay 28, which at its upper front contact connects battery to the filament circuit of amplifiers A_3, A_4 and A_2, thereby rendering these amplifiers operative. The corresponding relays at other intermediate stations render the entire four-wire circuit operative as soon as the plug is inserted in the jack at either terminal station. As soon as the operator at station D has completed the connection to a terminal two-wire line at that station, telephonic transmission may take place.

At the close of the conversation, the plug P_1 is withdrawn from the jack J_1 at station C, and the similar plug withdrawn at station D. Relays 27 and 21 at station D are now de-energized, and similar relays at the

other terminal station are also de-energized. Consequently the simplex circuit previously traced through relays 22 and 26 is again completed over the contact of relay 21 and its corresponding relay at station D, with both Morse batteries in series. Relays 22, 26 and the corresponding relay at station D are again energized. Relay 26, which is quick acting, thereupon attracts its armature and completes a circuit from ground over its front contact and over the lower front contact of slow acting relay 28, over the back contact of slow acting relay 29 and through the winding of relay 30 to battery. Relay 30 is now energized, and at its upper front contact, completes a locking circuit over the back contact of relay 24 to ground. At its lower front contact it completes a circuit from ground over the lower back contact of relay 24, lower front contact of relay 30, interrupting contact of stepping magnet 8, and through the winding of said magnet to battery. Stepping magnet 8 now intermittently interrupts its own circuit and advances the switch S step by step until the wiper S_1 engages a grounded contact, whereupon a circuit is completed from ground over the wiper S_1 and through the winding of relay 24 to battery. Relay 24 at its lower contact opens the locking circuit of the relay 30, which is now restored to normal, and also opens the self-interrupting circuit just traced for the stepping magnet 8 thus stopping the rotation of switch S. Relay 24 at its lower front contact completes a circuit for the slow release relay 29, which holds open the initial energizing circuit of the relay 30 to prevent the energization of the said relay 30 due to any further action of the relay 26. Relay 24 at its upper contact opens the simplex circuit, including the windings of relays 22, 26 and the corresponding relay at station D, so that these relays are again de-energized. A circuit is now completed from the positive battery 20 at station C over the back contact of relay 22 and through the winding of relays 6 and 3 to ground. Relays 6 and 3 are now energized and disconnect the four-wire circuit from the terminal arrangements and interconnect the ends of lines L_3 and L_4 through the transmission device M_1. In a similar manner the relays corresponding to relays 3 and 6 at station D are energized from the negative battery at said station, over the back contact of the relay corresponding to relay 22 at said station. Consequently the ends of the transmission lines L_3 and L_4 at station D are interconnected in a similar manner.

The relay 26 upon being de-energized again completes the circuit of slow acting relay 28, which closes the filament heating circuits of amplifiers A_3, A_4 and A_2. When the wiper S_1 of the switch S engages a grounded contact, the switch is in such position that the potentiometers P_3 and P_4 are set for the greatest amplification of amplifiers A_3 and A_4. Singing now takes place over the four-wire circuit, and the singing oscillations are transmitted through the transformer 17 and amplifier A_2 to the alternating current relay V, which is now actuated. Relay V opens the normally closed circuit through the relay 15, which is de-energized, and at its upper back contact closes a locking circuit for the relay 24, which therefore continues to hold open the simplex circuit. Relay 15 at its lower back contact completes a circuit from ground through interrupter 16, and through the winding of stepping magnet 8, which now advances the switch S gradually decreasing the amplification of amplifiers A_3 and A_4 until singing just ceases. When singing ceases, relay V is no longer energized, and the circuit of relay 15 is again completed, thereby opening the circuit of the stepping magnet and stopping the switch S, and also opening the circuit of relay 24. Relay 24 upon being de-energized again completes the simplex circuit through relays 22 and 26 and the corresponding relay at station D. These relays are now energized, relay 22 functioning to open the circuit previously traced through the windings of relays 3 and 6, which are de-energized and again connect the ends of the transmission lines L_3 and L_4 to the terminal arrangements. A similar action simultaneously takes place at the other terminal station. The relay 26, upon being again energized opens the circuit of the relay 28, which after a moment, is de-energized and opens the filament heating circuit for the amplifiers, rendering them again inoperative. The momentary circuit which would normally be closed over the front contact of relay 26, front contact of relay 28, through the winding of relay 30 is held open by the slow acting relay 29 until the relay 28 has had time to be de-energized. This prevents a false operation of the relay 30, which if operated, would disturb the setting of the potentiometers.

The switch S carries an additional wiper S_2 which is so arranged that if it is necessary to give an extremely high, or an extremely low setting to the potentiometer in order to secure the proper adjustment of the transmission circuit, said wiper S_2 will close a circuit through one or the other of a pair of signaling lamps 18 or 19, thereby indicating an abnormal condition of the circuit, which should receive especial attention. A relay 31 may be included in series with the lamps 18 and 19 to close a circuit to the pilot signal (not shown).

If the manual key 10 should be depressed and again relased, or if the contact 32, which is controlled by a suitable timing de-

vice, is opened and closed, the relay 21 will be energized to open and again close the simplex circuit as already described. This will result in the same series of operations as has been set forth with reference to putting up and taking down a connection; consequently the transmission equivalent of the four-wire circuit may be at any time regulated by simply pressing the key 10, and in any case the transmission equivalent will be adjusted at regularly recurring intervals by the operation of the switch 32, so that the circuit may be maintained at substantially constant efficiency.

It will 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. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifiers for said transmission lines, an automatic switch having a normal position and capable of movement in one direction only, means under the control of said switch for determining the amplification of said amplifiers, means to interconnect the ends of said transmission lines and to thereupon advance the switch from an abnormal position to its normal position, thereby setting said amplifying means for the highest degree of amplification so that singing takes place over the circuit formed by the interconnected pair of transmission lines, and means responsive to the singing thereby produced for advancing said switch until singing just ceases.

2. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifiers for said transmission lines, an automatic switch having a normal position and capable of movement in one direction only, means under the control of said switch for determining the amplification of said amplifiers, means to interconnect the ends of said transmission lines, means responsive to such interconnection for automatically advancing said switch until its normal position is reached, thereby setting said amplifying means for the highest degree of amplification so that singing takes place over the circuit formed by the interconnected pair of transmission lines, means responsive to the singing thereby produced, means operative in the normal position of the switch to shift the control of its further advancement to said singing responsive means, whereby the switch is again advanced until singing just ceases.

3. In a signaling system, a four-wire transmission circuit interconnecting two terminal stations and including a pair of transmission circuits for transmitting in opposite directions between said stations, normally inoperative amplifying means for said transmission lines located at an intermediate station, means controllable from a terminal station to render said amplifying means operative and to interconnect the ends of said pair of transmission lines, means to increase the amplification of said amplifying means so that singing takes place over the circuit thus formed, and means located at the intermediate station and responsive to the singing thus produced for gradually decreasing the amplification until singing just ceases.

4. In a signaling system, a four-wire transmission circuit interconnecting two terminal stations and including a pair of transmission lines for transmitting in opposite directions between said stations, normally inoperative amplifying means for said transmission lines located at an intermediate station, means controllable from a terminal station to render said amplifying means operative and to interconnect the ends of said pair of transmission lines, means responsive to the interconnection of said lines to increase the amplification of said amplifying means so that singing takes place over the circuit thus formed, and means located at the intermediate stations and responsive to the singing thus produced for gradually reducing the amplification until singing just ceases.

5. In a signaling system, a four-wire transmission circuit interconnecting two terminal stations and including a pair of transmission lines for transmitting in opposite directions, normally inoperative amplifying means for said transmission lines at an intermediate station, means at said terminal station to associate said four-wire circuit with terminating two-wire lines, means responsive to such associations to render said amplifying means operative, means responsive to the disconnection of the terminating two-wire lines from the four-wire circuit to interconnect the ends of said pair of transmission lines and to increase the amplification of the amplifying means so that singing takes place over the circuit thus formed, and means responsive to the singing thus produced for gradually decreasing the amplification of said amplifiers until singing just ceases.

6. In a signaling system, a four-wire transmission circuit interconnecting two terminal stations and including a pair of transmission lines for transmitting in opposite directions, means at a terminal station for connecting and disconnecting terminating two-wire lines to said four-wire circuit, means responsive to the connection and subsequent disconnection of the four-wire cir-

cuit and terminating two-wire lines to interconnect the ends of said pair of transmission lines and reduce the transmission loss of said transmission lines so that singing takes place over the circuit thus formed, and means at an intermediate station responsive to the singing thus produced to gradually increase the loss until singing just ceases.

7. In a signaling system, a transmission circuit for transmitting fluctuating signaling currents and including an adjustable transmission device, means operating automatically to adjust said transmission device in response to changes in the transmission condition of said transmission circuit so that the transmission circuit will have a predetermined transmission equivalent, and means to indicate an abnormal adjustment of said transmission device.

8. In a signaling system, a transmission circuit, signaling instruments for transmitting fluctuating signaling currents over said circuit, receiving instruments for receiving the signals thus transmitted, an adjustable transmission device in said transmission circuit, means functioning to periodically adjust said transmission device to compensate for variations in the transmission circuit so that the circuit when thus adjusted will have a predetermined transmission equivalent, and means in addition to said signaling and receiving instruments to indicate an abnormal adjustment of said transmission circuit, thereby indicating an abnormal condition of some other part of the transmission circuit.

9. In a signaling system a transmission circuit, signaling instruments for transmitting fluctuating signaling currents over said circuit, receiving instruments for receiving the signals thus transmitted, a signaling circuit, a transmission device controlled over said signaling circuit for adjusting the transmission equivalent of the transmission circuit, and means in addition to said signaling and receiving instruments for indicating an abnormal condition of the transmission device.

10. In a signaling system a transmission circuit extending between two stations, a transmission device in said circuit which is normally inoperative to transmit current, a signaling circuit, means controllable over said signaling circuit from either station for rendering said transmission device operative, and means controllable over said signaling circuit from either station to adjust the transmission of said transmission device, and thereby adjust the transmission equivalent of said transmission circuit.

In testimony whereof, I have signed my name to this specification this 9th day of September, 1918.

SAMUEL P. SHACKLETON.