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MEANS FOR AND METHOD OF REGULATING THE TRANSMISSION OVER ELECTRIC CIRCUITS

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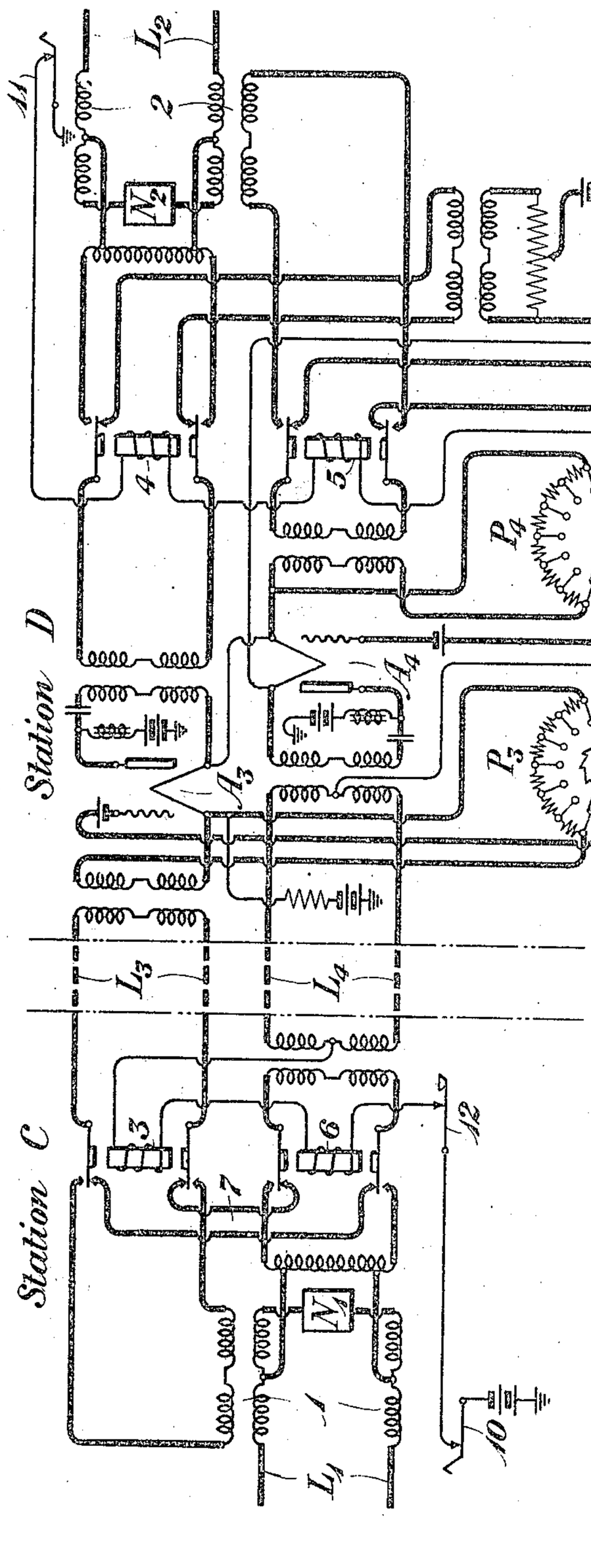

Fig. 2

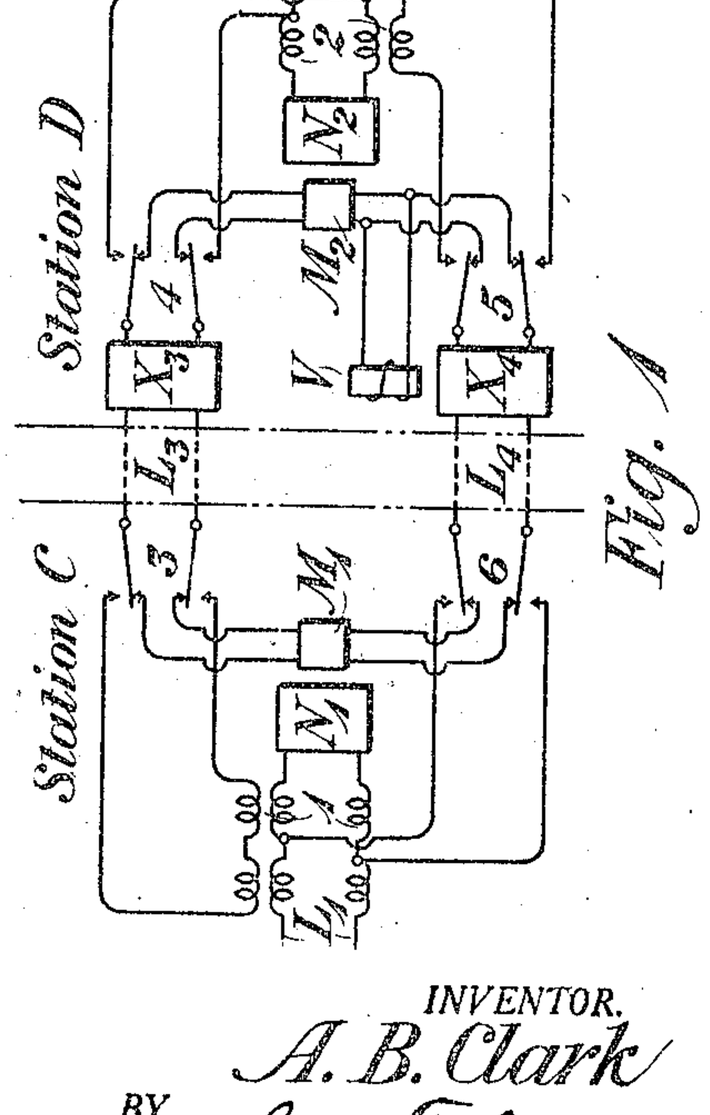

Fig. 1

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UNITED STATES PATENT OFFICE.

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

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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 substantially 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 insulations, 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 generally 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 eliminating these difficulties by varying some adjustable element of the transmission circuit to compensate for the variations introduced into the circuit. 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, where it is desired to take into account variations which do not affect both sides of the circuit alike, adjustment may be made for each side of the four-wire circuit separately to compensate for all causes of variation in either side. Where less precision is required, effects due to all possible variations in the two sides of the four-wire circuit may be compensated for by simultaneously varying like elements in the two sides of the circuit on the assumption that the two sides vary alike.

These methods may be carried out either manually or automatically and by making adjustments either continually with variations in the circuit, or at intervals of suitable frequency. For purposes of illustration, apparatus is disclosed for automatically carrying out the last method above mentioned, but it will be understood that manual apparatus may be employed if desired.

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 capable of introducing transmission losses or gains which together are adjusted to have 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 path thus formed will sing when the amplification therein exceeds the loss, and the circuit will have the proper transmission

equivalent when it is adjusted to a critical point at which singing just begins or just ceases. Accordingly by arbitrarily bringing the amplification of the path well below the singing point and then gradually adjusting the circuit independently of said interconnecting means until singing just begins, or by raising the amplification well above the initial singing point and gradually adjusting the circuit until singing just ceases, the circuit will be set for the proper transmission equivalent.

Where the latter method is employed the amplification in the closed path may be increased until it is greater than the total loss, 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 around this closed path and by gradually decreasing the amplification of similar amplifiers in the two transmission lines until singing just ceases, which occurs when the total amplification is approximately equal to the total loss, 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 a normal condition, in which the potentiometers are set 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 drawing, Figure 1 of which is a schematic diagram of an arrangement in which the invention may be embodied, while Fig. 2 is a circuit diagram showing an automatic apparatus for carrying out the invention, as applied to a four-wire circuit.

Referring to Fig. 1, a four-wire circuit is shown interconnecting two terminal stations C and D, said four-wire circuit comprising a pair of transmission lines L_3 and L_4 for transmitting in opposite directions. It will be understood that these transmission lines may include one way repeaters (not shown) for securing desired transmission over the circuit. At the terminal station the four-wire circuit may be associated by means of the usual three-winding transformers 1 and 2, with terminating two-wire lines L_1 and L_2, said two-wire lines being balanced by suitable artificial lines N_1 and N_2. When it is desired to adjust the transmission of the four-wire circuit the ends of the lines L_3 and L_4 may be disconnected from their terminal arrangements by means of relays 3, 4, 5 and 6, only the contacts of which are shown in Fig. 1. By means of these relays the ends of the lines L_3 and L_4 may be interconnected through the adjustable transmission devices M_1 and M_2 indicated schematically. These devices may be of any suitable character and should be so designed as to have a total transmission equivalent whose value is double and opposite in sign to, that to which it is desired the sides of the four-wire circuit exclusive of the terminal apparatus shall be adjusted. In other words, if it is desired to arrange the four-wire circuit so that each of its two sides will give a certain gain in transmission the devices M_1 and M_2 should together represent a transmission loss equal to twice the desired gain. On the other hand, if it is desired that there shall be a certain transmission loss in each of the two sides the devices M_1 and M_2 should comprise amplifiers, or other means whereby a total transmission gain equal to twice the desired loss may be produced. In order to simplify the arrangement, the devices M_1 and M_2 may be combined at one station so that at the other station the ends of the transmission lines L_3 and L_4 are directly connected. In order to adjust the transmission equivalent of the four-wire circuit, transmission varying devices X_3 and X_4 which will give either losses or gains may be provided in lines L_3 and L_4 respectively. These devices should first be set so as to make the amplification greater than the loss in the closed path through M_1, M_2, L_3, L_4, X_3 and X_4 so that singing will take place. A suitable arrangement such as the alternating current relay V will then respond to the singing thus set up, and the devices X_3 and X_4 may then be adjusted either manually, or automatically under the control of the device V, until the amplification is approximately equal to the loss, when the singing ceases. Under this condition, the total transmission equivalent of the complete loop is zero, so that the actual transmission equivalent of that portion of the loop comprising the lines L_3 and L_4, and the transmission varying devices X_3 and X_4 is equal to, but opposite in sign to, that of the devices M_1 and M_2. Assuming that the devices M_1 and M_2 have been properly set, the four-wire circuit will now have the desired transmission equivalent.

Turning now to Fig. 2, which shows in more detail an arrangement corresponding to that illustrated schematically in Fig. 1, it will be seen that amplifiers A_3 and A_4 are inserted in the lines L_3 and L_4 respectively, and correspond to the devices X_3 and X_4 respectively of Fig. 1. In order to control the amplification of these amplifiers, potentio-

meters P_3 and P_4 are provided, the setting of said potentiometers being determined by an automatic switch, including wipers S_3 and S_4. Relays 3, 4, 5 and 6 are shown for the purpose of disconnecting the transmission lines L_3 and L_4 from the terminating arrangement at stations C and D, and for interconnecting the ends of said lines in order to regulate the transmission thereof. At station C the lines L_3 and L_4 may be directly connected over path 7. At station D the ends of these lines are interconnected through an adjustable transmission device comprising an amplifier A_2 corresponding to the device M_2 of Fig. 1. Bridged across the path including the amplifier A_2 is an alternating current relay V, which responds to singing over the four-wire circuit to control the stepping magnet 8, whereby the switch including wipers S_3 and S_4, is advanced. The relays 3, 4, 5 and 6, as well as relay 9, are included serially in a simplex circuit passing over the two sides of the line L_4. Any other suitable circuit connecting the terminals of the four-wire circuit may, of course, be employed. This circuit is normally closed, but is opened by means of switches 10 and 11 when connections are completed over the two-wire lines L_1 and L_2 to the four-wire circuit, thereby deenergizing relay 9, and relays 3, 4, 5 and 6. Relays 3, 4, 5 and 6 upon being deenergized, connect the four-wire circuit to the terminal arrangement. The simplex circuit controlling these relays may also be opened by means of a switch 12 which may be either hand operated, or may be operated at regular intervals by means of a suitable timing arrangement. When the simplex circuit is again closed upon the taking down of the connection over lines L_1 and L_2, or by the closing of switch 12, the relays 3, 4, 5 and 6 again disconnect the four-wire circuit from the terminal arrangement and interconnect the ends of the lines L_3 and L_4. The relay 9 at the same time advances a commutator arrangement 13 one step so that the brush thereof passes over a live segment of the commutator and sends a momentary impulse through the release magnet 14 of the potentiometer controlling switch to restore said switch to its normal position, in which position singing takes place over the four-wire circuit, thereby actuating the alternating current relay V so that the switch is advanced step by step until singing just ceases.

Assuming that the amplifier A_2 has been properly adjusted as explained, upon completing a connection over lines L_1 and L_2 the switches 10 and 11 will be opened, thereby breaking the normally closed circuit through relays 3, 4, 5, 6 and 9. This circuit may be traced from battery, over switch 10, switch 12, through the windings of relays 6 and 3, thence in parallel over the two conductors of the transmission line L_4, through the windings of relays 9, 5 and 4, and over switch 11 to ground. Relays 3, 4, 5 and 6 release their armatures so that the ends of the transmission lines L_3 and L_4 are connected through the transformers 1 and 2 to the terminating two-wire lines, and conversation may now take place over the four-wire circuit. The release of magnet 9 permits its armature to retract and engage a new tooth of the commutator arrangement 13, but no circuit change results therefrom.

When the connection over lines L_1 and L_2 is taken down, switches 10 and 11 are again closed to complete the simplex circuit already traced through relays 3, 4, 5 and 6, and through magnet 9. Relays 3, 4, 5 and 6 disconnect the transmission lines L_3 and L_4 from the terminal arrangements and interconnect the ends of said lines through the amplifier A_2. The magnet 9 is energized at the same time, and in attracting its armature advances the commuator arrangement 13 one step, during which the brush of the commutator passes over a live segment thereof and again rests upon an insulating segment. A momentary impulse of current is thereby caused to flow through the release magnet 14, which withdraws the pawl carried by the armature of step magnet 8 from the ratchet wheel of the switch S_3 S_4 permitting the switch to be restored to its normal condition, as indicated in the diagram. With the switch in this position, potentiometers P_3 and P_4 are so set that the greatest degree of amplification is produced by the amplifiers A_3 and A_4 with the result hat singing takes place over the circuit, including the transmission lines L_3 and L_4 and the amplifier A_2. Alternating current relay V responds to the singing oscillations now produced, and closes a circuit from interrupter 15 over the front contact of relay V, and through the winding of step magnet 8 to batter The switch S_3 S_4 is now advanced step by step until singing just ceases, when the relay V releases its armature and the switch remains in its advanced position, with the potentiometers P_3 and P_4 so set that the transmission equivalent of each of the lines L_3 and L_4, exclusive of their terminating arrangements, is opposite in sign to and equal to one half that of the amplifier A_2. If, therefore, the amplifier A_2 has been properly set, the four-wire circuit will have the desired transmission equivalent. The potentiometers P_3 and P_4 will remain in their set positions, and the circuit is now in condition to be used.

The same result may be secured by opening and again closing the switch 12 either manually or by means of a time controlled device. It will also be obvious that the automatic switch arrangement may be eliminated, if desired, and the adjustment of the

potentiometers may be performed manually.

By means of the arrangement disclosed, a four-wire circuit may be adjusted so that it will have any desired transmission equivalent, regardless of variations which may take place in the circuit, so long as the variations affect both sides of the circuit alike. 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. In a four-wire circuit comprising a pair of transmission lines for transmitting in opposite directions and provided with means whereby said lines may be interconnected through terminal connections to terminal lines or connected together independently of said terminal connections, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop including the two lines of the four-wire circuit interconnected independently of the terminal connections, and producing a condition in the transmission path such that the amplification is greater than the loss, so that singing takes place, and gradually adjusting the circuit until the amplification becomes slightly less than the loss, so that singing ceases.

2. In a four-wire circuit comprising a pair of transmission lines for transmitting in opposite directions and provided with means whereby said lines may be interconnected through terminal connections to terminal lines or connected together independently of said terminal connections, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop including the two lines of the four-wire circuit interconnected independently of the terminal connections, and adjusting the circuit until a condition is reached determined by whether or not the circuit sings, under which the amplification in the loop is substantially equal to the loss.

3. In a four-wire circuit comprising a pair of transmission lines for transmitting in opposite directions and provided with means whereby said lines may be interconnected through terminal connections to terminal lines or connected together independently of said terminal connections, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop including the two lines of the four-wire circuit interconnected independently of the terminal connections, producing an abnormal transmission condition in the loop, and adjusting the transmission equivalent of the loop until the abnormal condition no longer exists.

4. In a four-wire circuit comprising a pair of transmission lines for transmitting in opposite directions and provided with means whereby the lines may be interconnected through terminal connections with terminal lines or interconnected independently of said terminal connections with a transmission device having a total transmission equivalent opposite in sign and twice that to which it is desired to adjust the four-wire circuit, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop including the two lines of the four-wire circuit with their ends connected together through said transmission device independently of the terminal connections, producing an abnormal transmission condition in the loop, and adjusting the transmission equivalent of the loop until the abnormal condition no longer exists.

5. In a four-wire circuit comprising a pair of transmission lines for transmitting in opposite directions and provided with means whereby said lines may be interconnected through terminal connections to terminal lines or connected together independently of said terminal connections, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop including the two lines of the four-wire circuit interconnected independently of the terminal connections, reducing the transmission loss in the path thus produced so that singing takes place, and gradually increasing the loss until singing just ceases.

6. In a four-wire circuit consisting of a pair of transmission lines for transmitting in opposite directions, each including amplifying means, said four-wire circuit being provided with means whereby said lines may be interconnected through terminal connections to terminal lines or connected independently of said terminal connections with transmission devices having a total transmission equivalent double and opposite in sign to that to which it is desired to adjust each side of the four-wire circuit, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop which consists of the two lines of the four-wire circuit with their ends connected independently of the terminal connections and through said transmission devices, increasing the amplification of said amplifying means until singing takes place over the loop thus produced, and gradually reducing the amplification until singing just ceases.

7. In a four-wire circuit comprising a pair of transmission lines for transmitting in op-

posite directions and provided with means whereby the lines may be interconnected through terminal connections with terminal lines or interconnected independently of said terminal connections with a transmission device having a total transmission equivalent opposite in sign and twice that to which it is desired to adjust the four-wire circuit, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop includng the two lines of the four-wire circuit with their ends connected together through said transmission device independently of the terminal connections, reducing the loss in the path thus produced so that singing takes place, and gradually increasing the loss until singing just ceases.

8. In a four-wire circuit comprising a pair of transmission lines for transmitting in opposite directions and each including amplifying means, said circuit being provided with means whereby the lines may be interconnected through terminal connections to terminal lines or connected independently of said terminal connections, the method of adjusting the transmission efficiency of the four-wire circuit, which consists in producing a transmission path over a loop including said pair of lines with their ends interconnected independently of the terminal connections, increasing the amplification of said amplifying means until singing takes place over the path thus produced, and gradually decreasing the amplification until singing just ceases.

9. In a signaling system, a two way repeater circuit, means for connecting the two sides of the circuit together to form a closed path in which singing will take place when the amplification in the path exceeds the loss, means to adjust the circuit, and means controlled by the singing of the circuit to bring the adjustment to an end when the amplification in the path is substantially equal to the loss.

10. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, means to interconnect the ends of said lines independently of terminal connections, and means to reduce the loss of said lines so that singing takes place over the circuit thus formed and to gradually increase the loss until singing just ceases.

11. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, means to interconnect the ends of said lines, means to reduce the loss of said lines so that singing takes place over the circuit thus formed, and means responsive to the singing thereby produced to gradually increase the loss of said lines until singing just ceases.

12. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifying means in said lines, means to interconnect the ends of said lines independently of terminal connections, and means to increase the amplification of said amplifying means so that singing takes place over the circuit thus formed and to gradually decrease the amplification until singing just ceases.

13. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifying means for said lines, means to interconnect the ends of said lines, means to increase the amplification of said amplifying means so that singing takes place over the circuit thus formed, and means responsive to the singing thereby produced to gradually decrease the amplification until singing just ceases.

14. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, means to interconnect the ends of said lines through a transmission device having a transmission equivalent opposite in sign and double that to which it is desired to adjust each side of the four-wire circuit, means to reduce the loss of said lines so that singing takes place over the circuit thus formed, and means responsive to the singing thereby produced to gradually increase the loss of said lines until singing just ceases.

15. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifying means for said lines, means to interconnect the ends of said lines through a transmission device having a transmission equivalent double and opposite in sign to that to which it is desired to adjust each side of the four-wire circuit, means to increase the amplification of said amplifying means so that singing takes place over the circuit thus formed, and means responsive to the singing thereby produced to gradually decrease the amplification until singing just ceases.

16. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, terminating two-wire lines to which the ends of said pair of transmission lines may be connected, means to disconnect said pair of transmission lines from the terminating two-wire lines and interconnect the ends thereof through a transmission device having a transmission equivalent double and opposite in sign to that to which it is desired to adjust each side of the four-wire circuit, means to reduce the loss in the four-wire circuit so that singing

takes place over the circuit thus formed, and means responsive to the singing thereby produced to gradually increase the loss until singing just ceases.

17. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifying means for said lines, terminating two-wire lines to which the ends of said pair of transmission lines may be connected, means to disconnect said pair of transmission lines from the terminating two-wire lines and interconnect the ends thereof through a transmission device having a transmission equivalent double and opposite in sign to that to which it is desired to adjust each side of the four-wire circuit means to increase the amplification of said amplifying means so that singing takes place over the circuit thus formed, and means responsive to the singing thereby produced to gradually decrease the amplification until singing just ceases.

18. In a signaling system, a four-wire transmission circuit including a pair of transmission lines for transmitting in opposite directions, amplifying means for said transmission lines, an automatic switch having a normal position and being adapted to be advanced therefrom or released and restored thereto, means under the control of said switch for determining the amplification of said amplifying means, means to interconnect the ends of said transmission lines and to release said switch, means responsive to the release of said switch for increasing the amplification of the amplifying means 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.

19. In a signalling system a pair of transmission circuits, each transmission circuit including amplifiers, and means for simultaneously adjusting the gain of the amplifiers in the two circuits while maintaining the normal plate potentials and filament currents of said amplifiers constant.

20. In a signalling system a pair of transmission circuits, amplifiers in each of said transmission circuits, and means for simultaneously adjusting the gain of the amplifiers in both circuits in the same direction while maintaining the normal plate potentials and filament currents of said amplifiers constant.

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

ALVA B. CLARK.