Aug. 16, 1927. **1,638,952**

H. NYQUIST

MEANS FOR REGULATING TRANSMISSION CIRCUITS

Filed Aug. 31, 1922 2 Sheets-Sheet 1

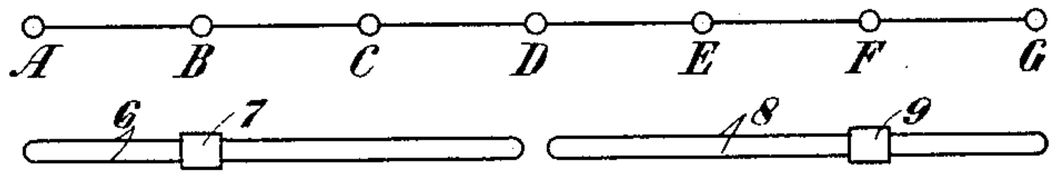

Fig. 1

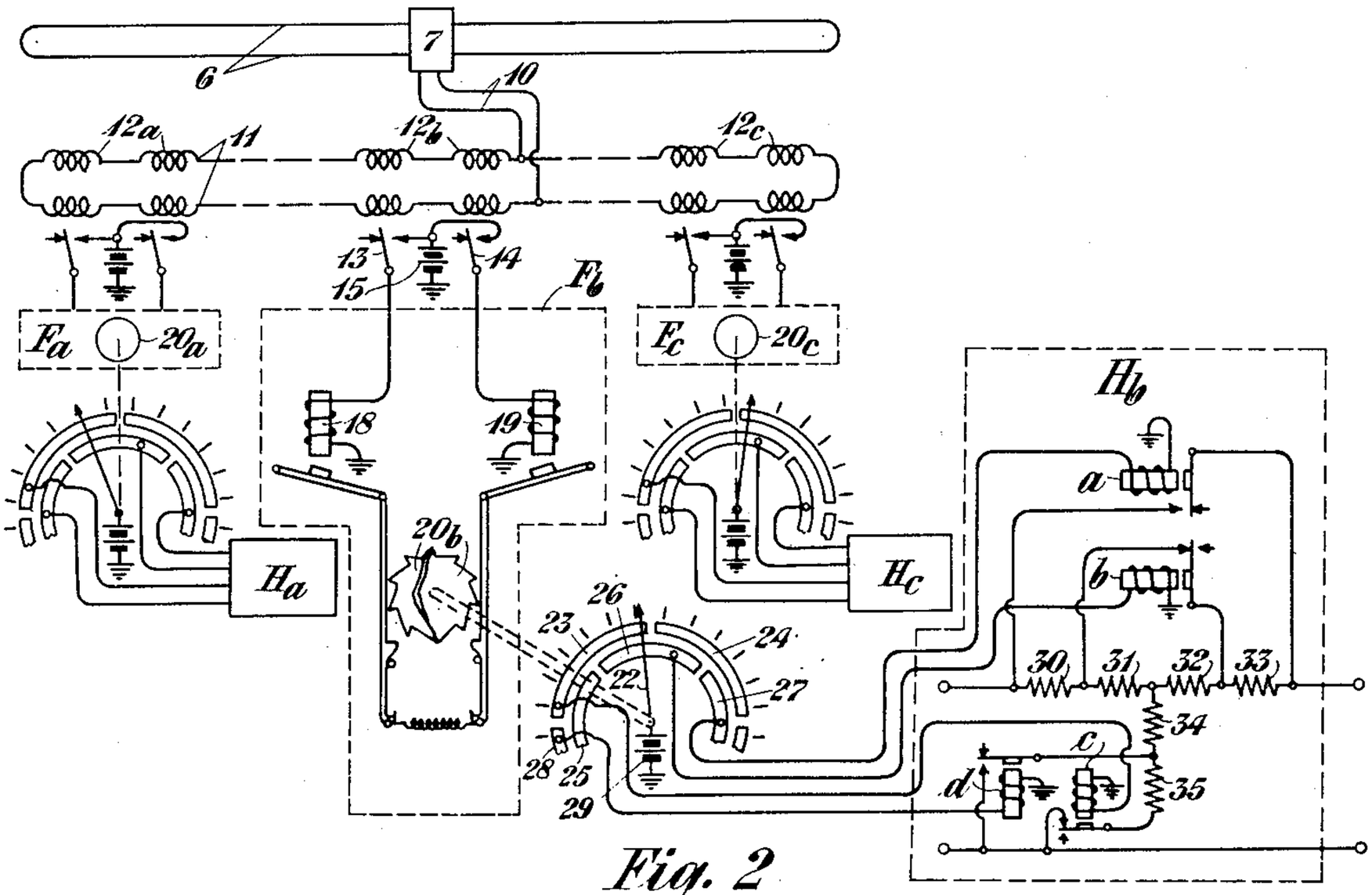

Fig. 2

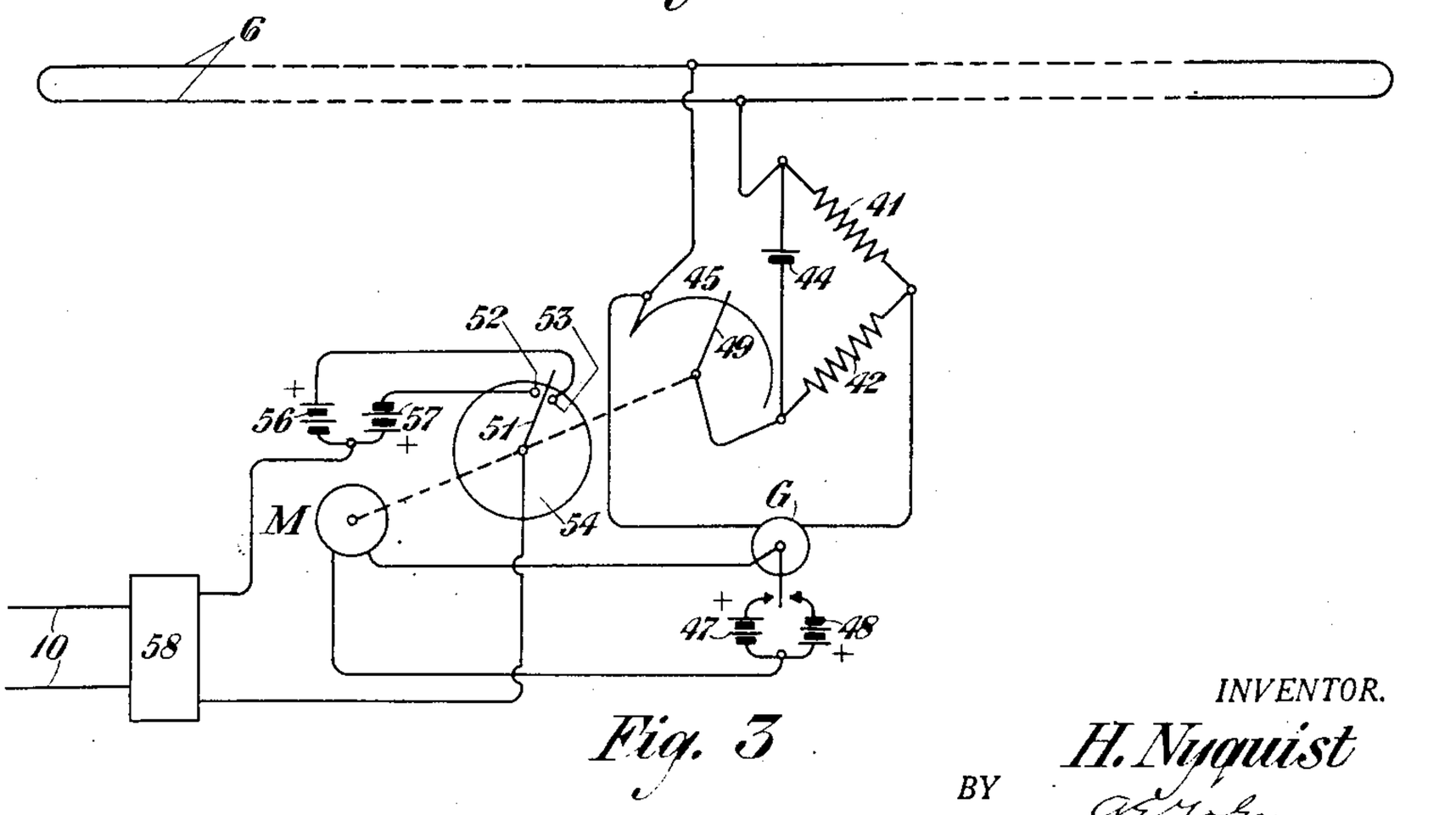

Fig. 3

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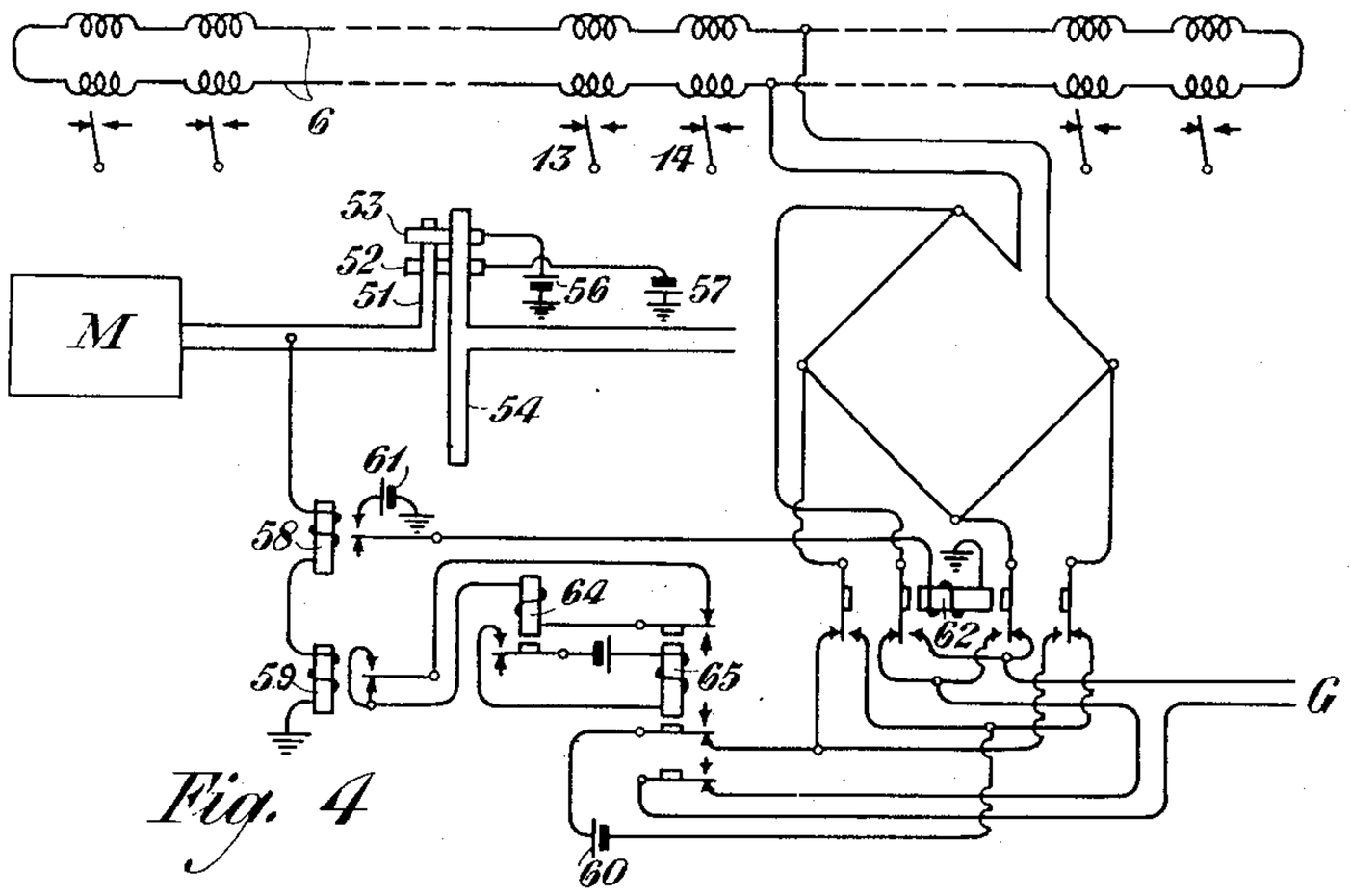

Fig. 4

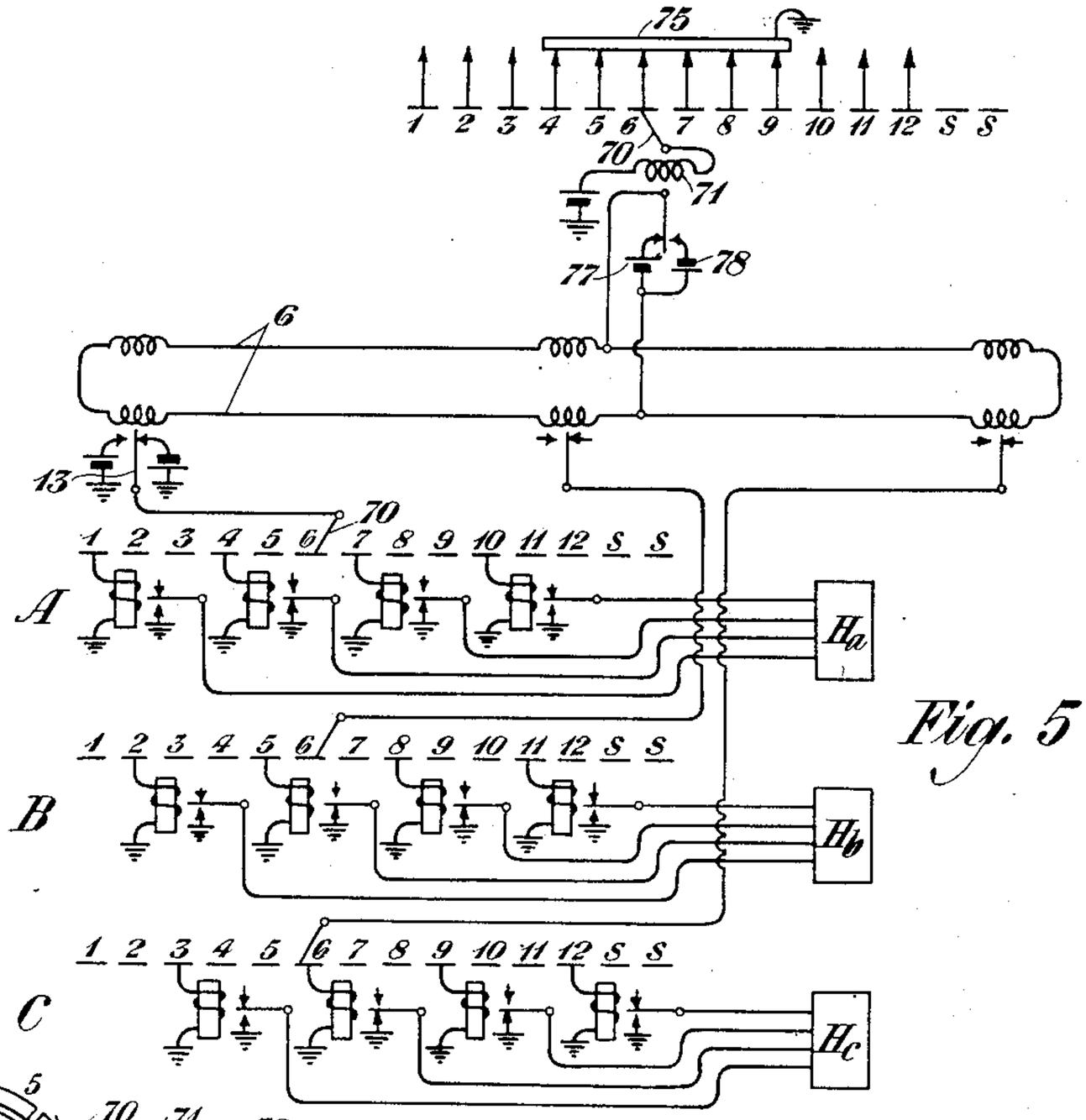

Fig. 5

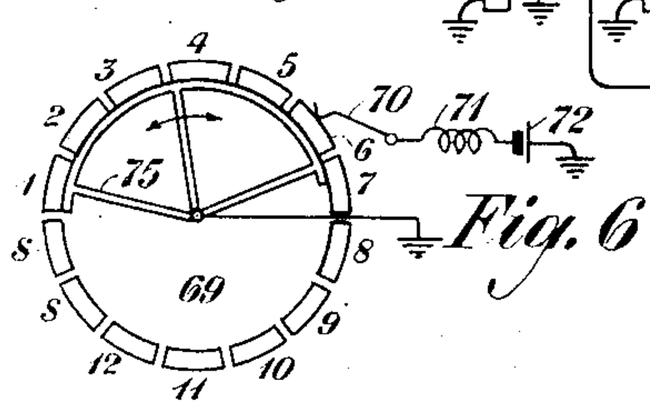

Fig. 6

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UNITED STATES PATENT OFFICE.

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MEANS FOR REGULATING TRANSMISSION CIRCUITS.

Application filed August 31, 1922. Serial No. 585,518.

This invention relates to means for regulating transmission circuits, and more especially the regulation of signaling lines, the regulation being introduced to compensate for changes in such lines due to varying climatic conditions.

Heretofore use has been made of such regulation especially in long telephone lines which carry a number of repeater stations. Usually a pair of wires paralleling the communication line, such as a pair in a cable, is set aside for the purpose of indicating the condition of the line over which transmission is to take place and which is to be regulated. On toll telephone lines, the most important climatic condition which must be considered is that of temperature variations, which will produce an alteration in the attenuation of the line, and, where the lines are long and the resistance great, the effect of this variation may be quite substantial.

As an illustration of the use of such regulation and the means for obtaining it, reference may be made to United States patent to A. B. Clark, No. 1,438,219 dated December 12, 1922, which describes in detail a circuit arrangement in which the pair of wires used for indicating the condition of the line, hereafter called the "pilot wires", is made one branch of a Wheatstone bridge. Fluctuations in the resistance of this pilot wire tend to unbalance the bridge and set into operation mechanism which will alter the gain due to a repeater installed in the communication line. It has not been considered, heretofore, economically feasible to introduce such a regulating mechanism at each repeater station, but it has been the practice to divide the line into regulator sections, each regulator section including several repeater stations. The regulating mechanism is then installed at one of the repeaters on this regulator section, preferably one near the middle of the section, and the total change in gain which should be introduced due to the changes over the whole regulator section is made at the one station, which may be called the "master station".

This system, as briefly described, has been a marked step in advance in the art, but it may occur that communication is carried on between two stations lying between two master stations, and the section of the line over which communication takes place does not include any regulator mechanism. On the other hand, the two stations between which communication is to be carried on may include a master station, but may not be the whole or the equivalent of a regulator section to which it belongs, and as a result there may be too much or too little regulation. Then, again, the concentration of the total regulation for a regulator section at one repeater may introduce a change so large as to overload the repeaters or introduce other deleterious effects. These effects are more noticeable in two-wire circuits than in four-wire circuits.

The object of this invention is to provide means by which more accurate regulation or more uniformly distributed regulation can be obtained without the necessity of placing a complete regulator installation at each repeater station and avoiding at the same time, certain disadvantages due to the possible operation of several such independent regulators simultaneously. I accomplish this by providing means for changing the gain at each repeater station, but controlling these means by mechanism at the master station. It is highly desirable that the gain control devices at the various repeater stations of a given regulator section are operated in sequence, each repeater thus being adjusted instead of having the total change concentrated at one station. The invention comprises means, then, by which impulses are transmitted over an impulse circuit which will affect the repeaters in sequence, introducing a gain or a loss, as may be determined by the condition of the pilot wire.

The invention will be better understood by reference to the accompanying drawings in which Figure 1 shows a circuit arrangement indicating the disposition of regulator sections and master regulator stations. Fig. 2 shows a circuit arrangement by which the gains of the repeaters at various stations are controlled in sequence. Fig. 3 shows a circuit connection with the pilot channel or wire by which the impulses are generated which control the mechanism of Fig. 2. Fig. 4 is a modified form of impulse generator which also uses one pair of wires for both a pilot channel and an impulse channel. Fig. 5 shows a further modification by which suitable impulses are transmitted to the various repeater stations to control the gain

of these repeaters and Fig. 6 is a detail of a part of the mechanism of Fig. 5.

Referring more particularly to Fig. 1, there is shown a telephone line with repeater stations A, B, C, etc. This, in general, is taken to represent a plurality of circuits such as may be enclosed in a cable. A section of this line comprising, for example, that portion which includes the repeaters A, B and C, is made one regulator section with one pair of wires 6 set aside as a pilot wire or channel. One of the stations, such as the station B, is made a master station and is supplied with equipment 7 by which, as hereinafter described, the gain of the repeaters A, B and C may be controlled. A similar pilot wire 8 with master controlling apparatus 9 is supplied for the section of the line including the repeaters D, E and F, and so for other portions of the line.

The details of such regulating mechanism are given in greater detail in Fig. 2 in which there is shown again the pilot wire 6 with mechanism 7, impulses from which are sent out in accordance with the condition of the pilot wire. These impulses travel out over a line 11, which, in general, parallels the pilot wire 6. In the example to be described, it is assumed that there are three repeater stations to be controlled. At each of these repeater stations there will be inserted in the impulse line 11 a double relay 12^a, 12^b or 12^c which is adapted to operate mechanism substantially the same at each of the stations. I have shown this apparatus in detail at one of the stations only, and, in particular, at the middle one, which, in general, will be the master station. Associated with the relay windings 12^b are two armatures 13 and 14. The two relays are polar relays such that the armature 13 will be drawn up on a positive impulse passing through the windings 12^b, and the armature 14 will be drawn up upon receipt of a negative impulse. Associated with the armatures 13 and 14 are two relays 18 and 19, the armatures of which are arranged to step a ratchet wheel 20^b in the one direction or the other. This stepping arrangement, shown as a whole by F_b, is duplicated at stations A and C as shown at F_a and F_c. Connected on the shaft of this ratchet wheel is a contact-making arm 22 which is adapted to pass over a number of commutator segments 23 to 28, certain of which are connected to relays *a*, *b*, *c*, and *d*, as will be hereinafter described. Connected to the contact arm 22 is a grounded battery 29. The relays *a*, *b*, *c*, and *d* are arranged to control impedances, some of which are in series and some in shunt to the input circuit of the repeater at the station B, and by the operation of one or another of the relays will adjust the input circuit in a manner to give suitable change in the gain of the repeater. This arrangement of relays *a*, *b*, *c*, and *d* with its associated network, and represented by H_b is duplicated at stations A and C as shown at H_a and H_c.

The operation of the circuit thus far described is as follows: If a positive impulse passes over the line, the armature 13 is drawn up. This connects battery to the relay 18, stepping ratchet wheel 20^b one step in the clockwise direction. This at the same time advances the contact arm 22 from the position shown in the drawing by one step. The position shown may be that corresponding to a normal gain for the repeater. Under these conditions, it will be observed that the relays *b* and *c* are operated, whereas the relays *a* and *d* are open. The closing of the relay *b* short-circuits the series impedances 31 and 32, and the closing of the relay *c* connects the impedances 34 and 35 across the line. In case it is desired to increase the gain of the repeater, it will be desirable to increase the impedance of the shunt or decrease the impedance of the series elements. Let us suppose that the temperature conditions of the line are such that it is desirable to increase the gain of the repeater by one unit corresponding, say, to one mile of gain in transmission. The drawing illustrates the case where this is accomplished by causing the arm 22 to advance one step in the clockwise direction. In this case the contact arm leaves the segment 23 and makes contact with the segment 24, retaining, however, its contact with the segment 26. Under these circumstances, the relays *a* and *d* remain open. In addition the relay *c* is opened, so that the shunt across the input of the receiver is removed. In case gain of another mile in this regulating section is desired, it should be produced at one of the other repeater stations, such as the station A. This is brought about by having the same arrangement of apparatus at the station A as at B with the difference, however, that the contact arm is displaced one step to the left of that at the station B. The second step, then, of the ratchet wheel at each of the stations A, B and C will produce no effect at the stations B and C, but will produce an effect at station A in the same manner as indicated for the previous step at the station B. Still another gain of one mile in transmission for the regulator section should be obtained by adjustment at the station C, and a fourth gain of one mile should be gained at the station B. It will be observed that the fourth step of the contact arm 22 at the station B causes a transfer of contact from the segment 26 to the segment 27. Leaving the segment 26 opens the relay *b* and closes the relay *a*, which short-circuits the whole series impedance. A fifth step would produce a similar effect at the station A, and a sixth step would produce a similar effect at the station C. Provision obviously could be made for fur-

ther steps of the same kind by having a more complex arrangement of impedances in series and in shunt to the line.

In case it is desired to reduce the gain, a negative impulse is sent over the impulse line, drawing up the armature 14. This operates the relay 19 to step the ratchet wheel and the contact arm 22 in a counterclockwise direction. The repeater at any one station is affected only every third step in the reverse order from that already described, and, after six negative impulses, conditions will be restored to those shown in Fig. 2. In case it is desired to further decrease the gain of the repeater, additional steps in the counterclockwise direction are taken. It will be observed that the first step will produce an effect at the station C; the second step backward will produce an effect at the station A; and a third step backward will produce an effect at the station B. In making this last step, it will be observed that at the station B the contact arm changes from the segment 26 to the segment 25. In this case the relay *b* is released and *c* alone remains closed. Under these circumstances, the whole series resistance is in circuit and the whole shunt impedance. In case further decrease in gain is desired, three steps more in the counterclockwise direction will cause the contact arm 22 at B to change from segment 23 to 28, closing relay *d* and thereby decreasing the value of the shunt impedance. Similar effects are produced at the stations A and C, the three operating in sequence in the manner indicated.

Fig. 3 shows the circuit arrangement for generating the impulses which are to actuate the relays of the impulse circuit. While such circuit arrangements may take on a large variety of forms, I have shown specifically a Wheatstone bridge arrangement of which the pilot wire constitutes one arm. Of the remaining arms, 41 and 42 will, in general, be fixed, and 45 will be variable to restore the bridge to balance. Across two corners of the bridge will be connected the battery 44 in the usual manner, and across the opposite two corners will be connected the galvanometer G. The needle of this galvanometer, acting as a relay, will connect a motor M with one or another of the batteries 47 and 48, depending upon the direction of the unbalance of the bridge, and thus causing the motor M to rotate in the one direction or the other. This motor M carries a shaft with which there is associated a contact arm 49, sliding along the variable resistance 45 in such a way as to continually tend to restore the balance of the bridge, and thus moving backwards and forwards in accordance with the fluctuations in the resistance of the pilot wire. The shaft of the motor also carries a contact arm 51, which is adapted to make contact with two terminals 52 and 53 on a disc 54, this disc being so mounted as to be carried along in the one direction or the other by the contact arm 51 when it contacts with 52 or 53. Oppositely poled batteries 56 and 57 are connected with the terminals 53 and 52 respectively, and a common terminal from the other side of these two batteries connects with one wire of the conductors 10, the second being connected with the contact arm 51. The relationship of the various members associated with the shaft of the motor M is that shown in Fig. 4, that portion of the shaft carrying the disc 54 and the arm 49 being an extension of the shaft of the ratchet 20^b.

The operation of the apparatus of Fig. 3 is as follows: In case there is a reduction in resistance of the pilot wire, the unbalance current through the galvanometer causes connection of the motor, resulting in a rotation of this motor in the direction to reduce the portion of the resistance 45 which is acting, that is, causing rotation of the contact arm 49 in the counterclockwise direction. This at the same time causes contact arm 51 to close with terminal 52, thus sending a positive impulse into conductors 10 which operates relay 19. Obviously a movement in the opposite direction would send out a negative impulse, and thus the control of the gain of the various repeaters described in Fig. 2 is controlled by the conditions of the pilot wire.

Fig. 4 shows a modification of the arrangement thus far described, it being proposed in this modification to use a single pair of wires, both as a pilot channel and as an impulse channel. This figure shows the pair of wires 6, comprising the pilot channel and in this circuit are introduced the relays which were formerly shown in the line 11. These relays and their armatures 13 and 14 operate apparatus which is the same as that explained in connection with Fig. 2. The circuit differs, however, in the manner in which the impulses are originated. The pilot wire 6 is again made one arm of a Wheatstone bridge to which there is connected as before the galvanometer G, controlling the direction of rotation of the motor M in the same manner as described above. The shaft of this motor M, also as before, carries the contact arm which tends continually to restore the balance of the bridge. It also carries the contact arm 51 and disc 54, by which positive or negative impulses are sent out from batteries 56 and 57. In this modification the impulses so sent out pass in series through two relays 58 and 59. Normally, current from the battery 60 is passing through the relays in the pilot wire 6 and the sending of signals consists in the interruption of this steady current. This battery 60 is the one normally supplied for the bridge and is so arranged through relays that its

direction may be reversed, the relays at the same time providing for a reversal of the galvanometer terminals.

The operation is as follows: The relay 58 is a polar relay, so constructed as to remain on either contact when there is no current in the winding. If, when in a neutral position, a positive impulse were to pass, the armature would be raised to make contact with the battery 61, thus operating the relay 62. This, as will be seen from the figure, reverses the battery connection to the bridge and also reverses the galvanometer connection, so that the motion of the motor M is not affected by the reversal. As long as positive impulses are sent out through the contact arm 51, the connection of the bridge remains fixed. These same impulses passing through the relay 59, which is associated with relays 64 and 65, cause an intermittent operation of contacts of the relay 65, thereby interrupting intermittently both the battery circuit 60 and the galvanometer circuit and thus impulses are sent out over the line 6, which impulses may be spoken of as positive impulses and which will produce operation of the armature 13 at the stations A, B and C to increase the gain of the various repeaters in the manner hereinbefore described.

In case it is desired to decrease the gain of the repeaters, due to the corresponding change in the resistance of the pilot wire 6, the motion of the motor M will be such as to send a negative impulse through the relays 58 and 59. This negative impulse through the relay 58 will cause a reversal of the battery and galvanometer connections to the bridge by breaking the circuit of the battery 61. These negative impulses will operate on the relay 59 in the same manner as before to cause an intermittent interruption of the battery and bridge connections by operation of the relay 65, thus sending out the equivalent of an impulse over the line 6. This impulse will, however, be in the opposite direction because of the reversal of the battery 60 and may therefore be spoken of as a negative impulse. This will therefore, operate the armature 14 and decrease the gain of the repeaters.

Still another modification for accomplishing the desired end is shown in Fig. 5. Here, again, one pair of wires is used, both as a pilot channel and an impulse channel. At the master station there is installed a rotating commutator, shown in more detail in Fig. 6 and consisting of a disc with 12 conducting segments, a brush 70, a polar relay 71 and a battery 72. The brush 70 is continually in rotation so that it is rapidly making contact with one after another of the segments. Mounted adjacent to the disc is a sector member 75, of sufficient angular opening to cover six of the segments, the sector being connected to ground. For simplicity I have shown in Fig. 5 the various segments arranged linearly rather than circularly, the sector 75 being shown as a straight bar. During that part of the rotation, when the brush 70 is in contact with a grounded segment, the relay 71 will be operated. Under these conditions positive impulses from battery 77 are transmitted over the pilot channel 6. In case the rotating brush 70 is in contact with any of the other segments on the stationary disc, the relay 71 will not be operated and the armature makes contact with battery 78 to send negative impulses over the pilot channel 6.

At each of the repeater stations there is installed a similar disc with corresponding segments but without the sector 75. The brushes 70 on each of these are caused to rotate in synchronism with the brush 70 at the master station. Thus, when this brush 70 is in contact, as shown, with the segment 6 of the master disc, it is in contact with the same segments at the three repeater stations. With the discs at each of the stations there are associated four relays. At station A these are connected respectively with segments 1, 4, 7 and 10, that is, with every third segment. Similarly, at station B, the relays are associated with segments 2, 5, 8 and 11 and at station C with segments 3, 6, 9 and 12. The armatures of these relays are included in circuit with relays *a*, *b*, *c* and *d*, which control the series and shunt impedances shown with that portion of Fig. 2 designated as H_b, and thus control the gain of the repeaters. The sector 75 is controlled in its position and caused to rotate in one direction or the other by the motor, which in turn is controlled by the bridge of Fig. 3. As this shifts forward or backwards, then, a different group of segments of the master relay are grounded and thus either positive or negative impulses are transmitted to the line 6, causing corresponding operation of the armatures 13 and 14.

In addition to the twelve segments on the discs it will be desirable to have certain segments which may be set aside for sending the necessary impulses to maintain synchronism between the rotating brushes at the various stations, and in the Fig. 6 I have shown two such segments marked S, S, for this purpose.

Obviously, many modifications other than those described could be devised for accomplishing the same purpose and I do not wish to be limited to the specific modifications disclosed, these being used for illustrative purposes only.

What is claimed is:

1. In a telephone transmission system, a telephone line, a plurality of repeater stations on said line and means at one station, responsive to variations in the physical con-

dition of the line, for varying the repeater gains at a plurality of the repeater stations.

2. In a telephone transmission system, a telephone line, a plurality of repeater stations on said line, means at each station for varying the repeater gain in any one of a plurality of degrees, and means at one of said stations for controlling the first said means at the other stations.

3. In a telephone transmission system, a telephone line, a plurality of repeater stations on said line and means at one station for varying the repeater gains at a plurality of the repeater stations in any one of a plurality of degrees.

4. In a telephone transmission system, a telephone line, a plurality of repeater stations on said line, means at one station for varying the repeater gain at a plurality of the repeater stations, and means for causing the stations to be affected in sequence order.

5. In a telephone transmission system, a telephone line, a pilot channel adjacent thereto, a plurality of repeaters on said line, means at each station for controlling the amplification in accordance with the physical condition of the pilot channel and means at one of said stations for controlling the first said means at the other stations.

6. In a telephone transmission system, a telephone line, a pilot channel adjacent thereto, a plurality of repeaters on said line, means at each station for controlling the amplification in accordance with the physical condition of the pilot channel, means at one of said stations for controlling the first said means at the other stations, and means for causing the stations to be affected in sequence order.

7. In a telephone transmission system, a telephone line, a pilot channel adjacent thereto, a plurality of repeater stations on said line, means at each of said stations for controlling the amplification and means at one of said stations, responsive to the physical condition of the pilot channel, for generating and transmitting impulses to the various stations for controlling the first said means, the stations being affected in sequence order.

8. In a telephone transmission system, a telephone line, a plurality of repeater stations thereon, a plurality of pilot wires in succession and each adjacent to a section of the line, means at each station for controlling the gain of the repeaters, the approximate mid-station of each section constituting a master station, means at each master station associated with and responsive to the condition of the line for controlling the first said means at each of the stations in its section.

9. In a telephone transmission system, comprising a telephone line with repeaters and a pilot channel, the method of maintaining approximately constant transmission level which consists in sending out impulses from one repeater station in accordance with the physical condition of the pilot channel and controlling thereby the gain at the various repeater stations.

10. In a telephone transmission system, comprising a telephone line with repeaters and a pilot wire, the method of maintaining approximately constant transmission level which consists in sending out impulses from one repeater station in accordance with the physical condition of the pilot wire and controlling thereby the gain at the various repeater stations, the stations being affected in sequence order.

In testimony whereof I have signed my name to this specification this 24th day of August, 1922.

HARRY NYQUIST.