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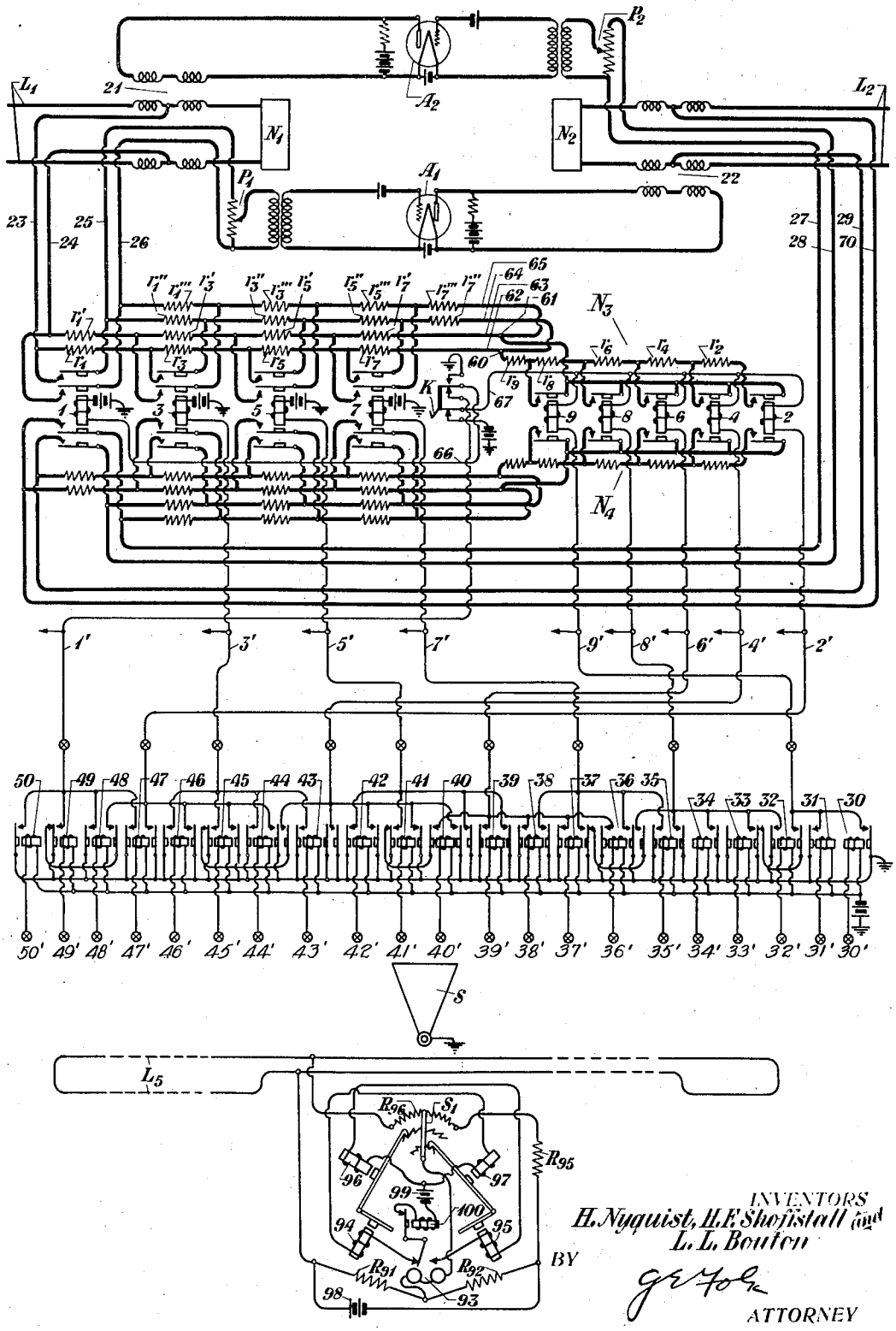

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UNITED STATES PATENT OFFICE.

HARRY NYQUIST, OF ELMHURST, NEW YORK, LEWIS L. BOUTON, OF LEONIA, NEW JERSEY, AND HUGH F. SHOFFSTALL, OF NEW YORK, N. Y., ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

GAIN-CONTROL CIRCUITS FOR REPEATERS.

Application filed September 12, 1923. Serial No. 662,284.

To all whom it may concern:

Be it known that we, HARRY NYQUIST, LEWIS L. BOUTON, and HUGH F. SHOFFSTALL, residing at Elmhurst, Leonia, and New York, in the counties of Queens, Bergen, and Bronx and States of New York, New Jersey, and New York, respectively, have invented certain Improvements in Gain-Control Circuits for Repeaters, of which the following is a specification.

This invention relates to transmission circuits and more particularly to transmission circuits including repeaters, such, for example, as two-way two-element repeaters.

One of the principal objects 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. In general, the transmission equivalent of a circuit varies, due to a number of different causes. One of the main causes of variation is due to variations in the resistance, due to temperature changes. Among other causes may be enumerated variations in capacity, inductance, or other electrical characteristics of the line and also variations in the potential of repeater batteries common to repeaters in both sides of the circuit. Variations may also be caused by changes in insulation or in structure of apparatus associated with the lines.

The present invention contemplates eliminating these difficulties by automatically varying some adjustable element of the transmission circuit to compensate for the variation introduced in said circuit. The objects of the invention are secured as herein disclosed by causing a suitable translating apparatus to be actuated in accordance with changes in the electrical character of some one of a group of circuits. The remaining circuits of the group are then adjusted to compensate for the changes indicated by the first circuit. More specifically, these results are accomplished by arranging the first mentioned or pilot circuit in one element of a Wheatstone bridge arrangement, so that variable currents will flow through the bridge with variations in the conductivity of the pilot circuit. Apparatus in the bridge circuit is so arranged as to respond to the currents flowing therein to control an automatic switch for adjusting a transmission varying device associated with the transmission circuit. The transmission varying device of this invention comprises an artificial line including a plurality of series and shunt elements and associated with the input circuits of the repeaters. The actuation of the automatic switch will operate to cut into the circuit more or less of the artificial line elements and thus vary the repeater gain to compensate for changes or variations in the transmission equivalent of the circuit. Other objects and features of the invention will be clear from the detailed description of the invention hereinafter given.

The invention may be more fully understood from the following description, together with the accompanying drawing in which is illustrated a circuit diagram of the arrangements of the invention.

In the drawing are shown two sections L_1 and L_2 of a transmission line interconnected by a two-way, two-element repeater comprising the vacuum tube amplifiers A_1 and A_2, the potentiometers P_1 and P_2, the three-winding transformers 21 and 22, and the balancing networks N_1 and N_2. The input of amplifier A_1 is bridged across the midpoints of windings 21 by means of conductors 23, 24 and 25, 26. Associated with these conductors is the transmission varying device, comprising the artificial line N_3. The artificial line N_3 includes the conductors 62, 63, 64 and 65, which interconnect conductors 23, 24, and 25, 26. Conductors 62, 63, 64 and 65 include the series resistances r_1, r_3, r_5, r_7, r'_1, r'_3, r'_5, r'_7, r''_1, r''_3, r''_5, r''_7, r'''_1, r'''_3, r'''_5, and r'''_7 in the manner shown. Included in a circuit whereby they may be bridged across conductors 62 and 63 at points 60 and 61 are the resistances r_9, r_8, r_6, r_4 and r_2. The relays 1, 3, 5, 7 and 9, 8, 6, 4, 2 are provided to control shunts about these resistances whereby more or less of the first group of resistances may be included in series in both sides of the input circuit of amplifier A_1 and more or less of both groups of resistances may be connected in shunt across said circuit. Accordingly, by operating certain of these relays the elements of artificial line N_3 may be varied to control the gain of the repeater circuit of amplifier A_1 and thus compensate for variations in the transmission equivalent of the line L_1.

The input of amplifier A_2 is bridged across the midpoints of windings 22 by means of conductors 27, 28 and 29, 70. Associated with these conductors is the transmission varying device comprising the artificial line N_4. The artificial line N_4 is identically the same as artificial line N_3 and its elements may be cut in or out of the input circuit of amplifier A_2 by means of shunt paths controlled by the lower contacts of relays 1 to 9 inclusive to control amplifier A_2 to compensate for changes in the transmission equivalent of line L_2. The variations of the elements in line N_3 to control the effective gain of amplifier A_1 not only compensates for variations in line L_1 but also in line L_2 and thus holds the transmission constant in the direction from L_1 to L_2. Network N_4 associated with amplifier A_2 holds the transmission constant in the direction from L_2 to L_1 in a similar manner. As artificial line N_4 is the same as artificial line N_3 no further description thereof will be given.

The relays 1, 3, 5, 7 and 9, 8, 6, 4, 2 are controlled over conductors 1′, 3′, 5′, 7′ and 9′, 8′, 6′, 4′, 2′ by a series of master relays 50 to 30 inclusive. The master relays are controlled by the contacts 50′ to 30′ inclusive by means of the switch S, which in turn is controlled by the pilot wire circuit L_5. The pilot wire circuit L_5 is included in the same cable and is subject to the same conditions as the line, such as line sections L_1 and L_2 the variations in which are to be compensated for. The pilot circuit L_5 is included in one branch of a Wheatstone bridge in which the resistance R_{95}, which may be equivalent to the average resistance of the pilot circuit L_5, forms a second branch. Resistances R_{91} and R_{92} respectively constitute the third and fourth branches. In circuit with the pilot circuit L_5 and the resistance R_{95} is an adjustable resistance R_{96} for balancing the bridge, said resistance being controlled by a wiper S_1 carried by the switch S. The wiper S_1 is included in the bridge circuit of the Wheatstone balance, the said circuit also including a polarized relay 93 which controls the operation of the switch S through the medium of the stepping magnets 94 and 95 and the holding magnets 96 and 97. Assuming that a change takes place in the resistance of the pilot circuit L_5, due to a change in temperature or other cause, the Wheatstone bridge is unbalanced and a current flows over the bridge circuit through the winding of the polarized relay 93 and over the wiper S_1. If the resistance of the circuit L_5 is increased, this current is in such a direction as to throw the armature of the polarized relay 93 to the left, as shown in the drawing, thereby completing a circuit from battery 99, through the winding and over the back contact of buzzer relay 100, over the left-hand contact of polarized relay 93, winding of stepping magnet 94 and winding of release magnet 97. The release magnet 97 draws the pawl carried by the armature of stepping magnet 95 from engagement with the corresponding ratchet wheel and the stepping magnet 94 operates its ratchet wheel step by step with each interruption of the circuit by the buzzer relay 100 to rotate the wiper S_1 in counter-clock-wise direction. The division of the resistance R_{96} between the arms of the bridge including the pilot circuit L_5 and the resistance R_{95} is thereby changed until the Wheatstone bridge is again balanced. This action moves the switch S in a counter-clock-wise direction, thereby affecting the master relays and the relays controlling the artificial line N_3 to increase the gain of the repeater in the direction from L_1 to L_2, as will be pointed out in detail hereinafter. If the change in the condition of the pilot circuit L_5 is of such nature as to cause a reduction of the resistance, the current flows through the windings of the polarized relay 93 in the opposite direction and a circuit is closed through the buzzer relay 100, stepping magnet 95 and release magnet 96 to step the switch S in a clockwise direction, thereby affecting the master relays and the artificial line relays to decrease the gain of the repeater in the direction from line L_1 to L_2.

When the key K is operated, ground will be applied over its upper contact to conductor 66 and through the winding of relay 1 to battery and ground, thereby operating relay 1. At the same time, battery will be removed at the lower contact of key K from conductor 67 and will prevent any energization of the relays 9, 8, 6, 4 and 2. Upon the operation of relay 1, conductors 23 and 24 will be connected directly to conductors 25 and 26 over the contacts of relay 1 and none of the series resistance elements, such as r_1 or r'_1 will be included serially in the input circuit of the amplifier. Due to the fact that none of the relays 9, 8, 6, 4 and 2 are operated, the shunt path, including the shunt resistances r_9, r_8, r_6, r_4 and r_2 will be open and none of these resistance elements or the other series resistance will be bridged across the input of the amplifier A_1. Under these conditions the amplifier A_1 will operate in the normal manner, irrespective of the artificial line N_3. With the key K closed, as shown, battery is applied over its lower contact to the conductor 67 and thence in parallel to the windings of relays 9, 8, 6, 4 and 2, placing them in a state ready to be energized upon the grounding of conductors 9′, 8′, 6′, 4′ and 2′ respectively. Conductor 66 will also be connected to conductor 1′. If ground is now applied through the master relays to conductor 1′ the relay 1 will operate and con-

ductors 23 and 24 will be connected to conductors 25 and 26, as before and the amplifier A will operate at its maximum gain. Under these conditions all of the series resistances would be short circuited. The switch S would next cause ground to be applied to conductor 2′, which would cause the operation of relay 2, while at the same time maintaining relay 1 energized. Upon the operation of relay 2, the shunt circuit, including shunt resistances r_9, r_8, r_6, r_4 and r_2 will be closed and will be bridged at points 60 and 21 across the conductors 62 and 63. Under these conditions all of the resistance elements, both series and shunt, will be bridged across conductors 23, 24 and 25, 26, or in other words across the input circuit of the amplifier A_1, thereby tending to diminish the gain of the amplifier. The operation of the switch S and the master relays will next cause ground to be applied to conductor 3′. This will operate relay 3 and at the same time maintain relay 2 energized. Under these conditions conductors 23, 24 will be connected to conductors 25, 26 through the resistance elements r_1, r'_1, r''_1 and r'''_1 over the contacts of relay 3. In other words these last mentioned series resistances will be included serially in the input circuit of the amplifier. The shunt resistance across the input of the amplifier however will be reduced as these last mentioned elements are now connected serially therein. Accordingly, under these conditions, we will have a slight decrease from the full shunt resistance of the artificial line across the input circuit and a portion of the series resistance included in the input circuit. This will tend to further decrease the gain of the repeater in the direction from line L_1 to L_2. The switch S will next apply ground to conductor 4′, thereby operating relay 4 and at the same time maintain relay 3 energized. Upon the operation of relay 4 a short circuit will be closed about resistance r_2. Accordingly, this will reduce the shunt resistance across the input circuit of the amplifier and tend to further decrease the gain of the amplifier. The switch S and the master relays would next apply ground to conductor 5′, thereby operating relay 5 and maintaining relay 4 energized. Under these conditions the series resistance elements r_3, r'_3, r''_3 and r'''_3 would be included serially in the input circuit of amplifier A_1, together with the resistances r_1, r'_1, r''_1 and r'''_1 instead of being connected in shunt across said input circuit as before. This would tend to further decrease the gain of the amplifier. The switch S and the master relays would in like manner operate in sequence the relays 6, 7, 8 and 9, thus continuing to alternately decrease the shunt resistance across the input path of the amplifier and to increase the series resistance in the amplifier to gradually decrease the gain thereof.

It is pointed out that an advantageous feature of these arrangements consists in the fact that the variable artificial lines N_3 and N_4 are so constructed of series and shunt resistances that when the attenuation loss is varied, nevertheless the variation in the impedance of one of these lines presented to the circuit in either direction remains practically constant. This feature is obtained in the heretofore described arrangements by first increasing the series elements, second decreasing the shunt elements, third increasing the series elements, and fourth further decreasing the shunt elements. The first and third changes increase the impedance of the artificial line, while the second and fourth decrease it, so that the changes in attenuation are obtained by a relatively simple switching arrangement but without bringing about wide variations in impedance.

Let it be assumed that switch S is resting on contact 50′. This would close a circuit from ground through switch S, contact 50′, winding of relay 50, over conductor 52 to battery and ground, thereby energizing relay 50. The energization of relay 50 would apply ground to conductor 1′ over the contact and armature of relay 50 and conductor 51. When the switch S moved to contact 49′ relay 49 would, in like manner, be energized and apply ground to conductor 1′. Upon touching contact 48′ the switch S would cause relay 48 to be energized. This would apply ground to conductor 1′ and as soon as the switch left the conductor 49′ would cause ground to be applied from the left-hand contact of relay 49, over the right-hand contact of relay 48, to conductor 2′. When the switch S moves to contact 47′ ground will still be applied over the left-hand contact of relay 47 to conductor 1′ and ground will also be applied over the right-hand contact of said relay to conductor 2′. When the switch S rests on contact 46′, relay 46 will operate and apply ground to conductor 3′ over its left-hand contact and apply ground to conductor 2′ over its right-hand contact, thereby maintaining both the relays 2 and 3 energized at the same time. When the switch S touches contact 45′ relay 45 will operate and apply ground over its right-hand contact to conductor 2′ and over its left-hand contact to conductor 3′. When the switch S touches contact 44′, relay 44 will operate. This will apply ground over its left-hand contact to conductor 3′ and over its right-hand front contact to conductor 2′ and over its right-hand back contact of conductor 4′, thereby maintaining relays 2, 3 and 4 in an energized condition. In a similar manner the switch

S, by moving along the remaining contacts, will operate the master relays in sequence and will operate the relays of the artificial line in numerical order. As has been pointed out, this will alternately add series resistance elements to the input circuit and cut out the resistance elements connected in shunt across said circuit and will thus gradually decrease the gain of the amplifier.

To control the gain of the repeater in the direction from line L_2 to L_1 the pilot circuit is also included in the same cable or subject to the same conditions as the line L_2. The pilot circuit, as heretofore described, would control switch S, which would cooperate with the contacts 50′ to 30′ inclusive to control the master relays, which in turn would control the relays 1 to 9 inclusive to change the resistance elements of the line N_4, which would be included in the input circuit of amplifier A_2. As this operation would be substantially the same as that heretofore described with respect to the artificial line N_3 no further description thereof will be given.

The conductors 1′, 2′, 3′, 4′, 5′, 6′, 7′, 8′ and 9′ may be multipled to other relays similar to relays 1 to 9 inclusive to control other artificial lines or transmission vary means to control the gain of other repeaters used on lines which are subject to the same variations as the pilot circuit L_5.

While the invention has been disclosed as embodied in certain specific arrangements which are deemed desirable it is understood that it is capable of embodiment in other and different forms within the spirit and scope of the appended claims. The arrangements of the invention, for example, might equally well be associated with a cord circuit repeater rather than a through line repeater set.

What is claimed is:

1. In a signaling system, a plurality of transmission circuits subject to similar variations in their electrical characteristics, one of said circuits being a pilot circuit, means associated with said pilot circuit responsive to changes in the electrical characteristics thereof, and means controlled by said responsive means for varying the characteristics of the other circuits in accordance with the variations in the characteristics of said pilot circuit, said last mentioned means comprising a transmission varying device.

2. In a signaling system, a plurality of transmission circuits subject to similar variations in their electrical characteristics, one of said circuits being a pilot circuit, a telephone repeater in one of said circuits, means in said pilot circuit responsive to changes in the electrical characteristics thereof, and a variable artificial line associated with the input of said telephone repeater controlled by said responsive means for varying the characteristics of said repeater circuit in accordance with the variations in the characteristics of said pilot circuit.

3. In a signaling system, a plurality of transmission circuits including repeater apparatus, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, switching means, means to automatically set said switching means in accordance with the electrical condition of said pilot circuit, transmission varying devices associated with said repeater apparatus, and means controlled by said switching means for controlling said transmission varying devices whereby the gain of said repeater apparatus may be varied.

4. In a signaling system, a plurality of transmission circuits including repeater apparatus, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, switching means, means to automatically set said switching means in accordance with the electrical condition of said pilot circuit, variable artificial lines associated with said repeater apparatus, relays for controlling said artificial lines, and a set of master relays controlled by said switching means for controlling said relays.

5. In a signaling system, a plurality of transmission circuits including repeater apparatus, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said said transmission circuits, switching means, means to automatically set said switching means in accordance with the electrical condition of said pilot circuit, variable artificial lines associated with the input circuits of said repeater apparatus and comprising a plurality of series and shunt resistances, relays for closing shunts about certain of said resistance elements whereby the amount of series and shunt resistance associated with said repeater input circuits may be varied, and a set of master relay controlled by said switching means for controlling said relays.

In testimony whereof, we have signed our names to this specification this 11th day of September, 1923.

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