March 6, 1928. 1,661,263

H. NYQUIST

METHOD OF AND MEANS FOR REGULATING THE TRANSMISSION OVER ELECTRIC CIRCUITS

Filed Feb. 19, 1923 2 Sheets-Sheet 1

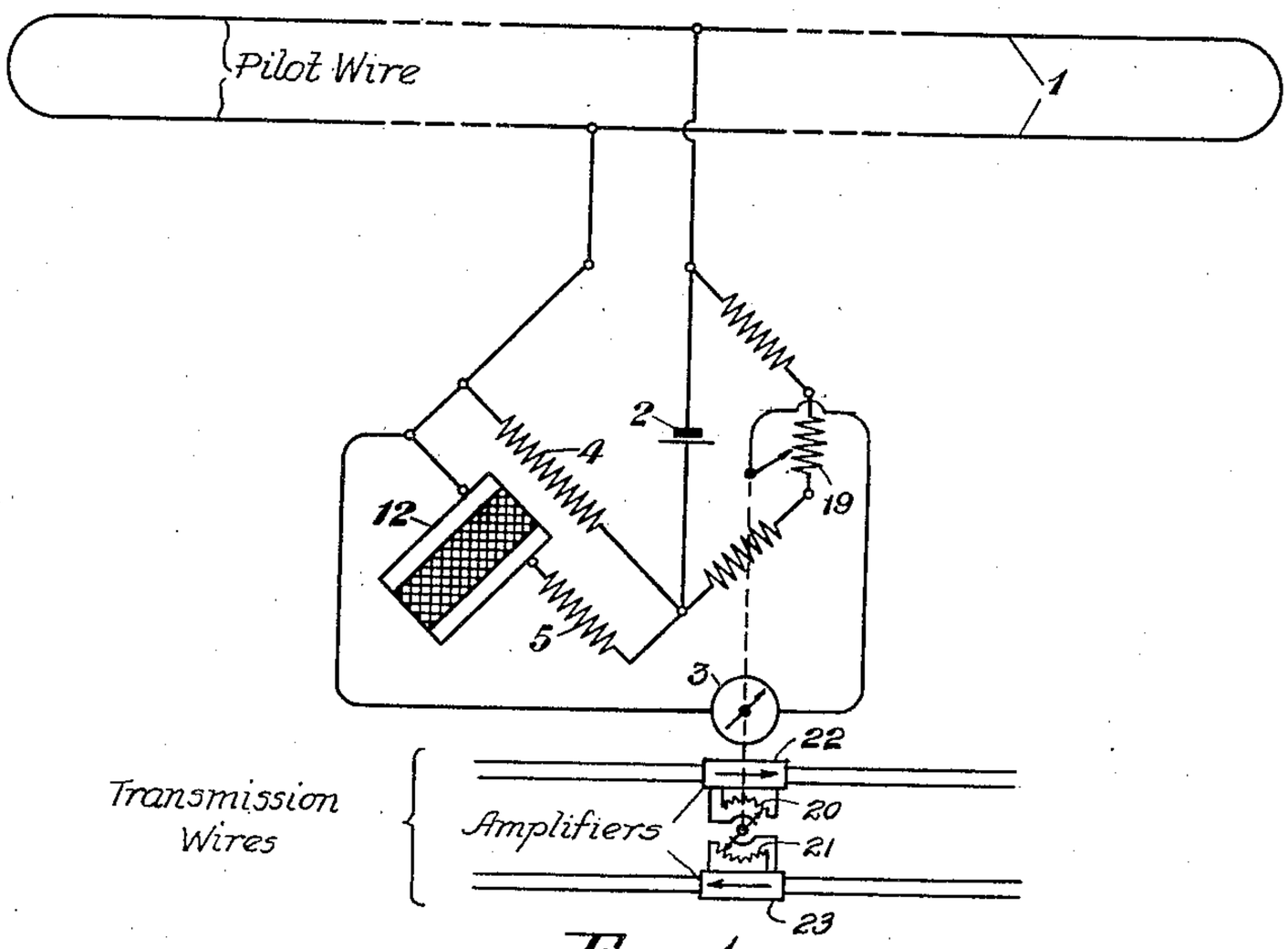

Fig. 1

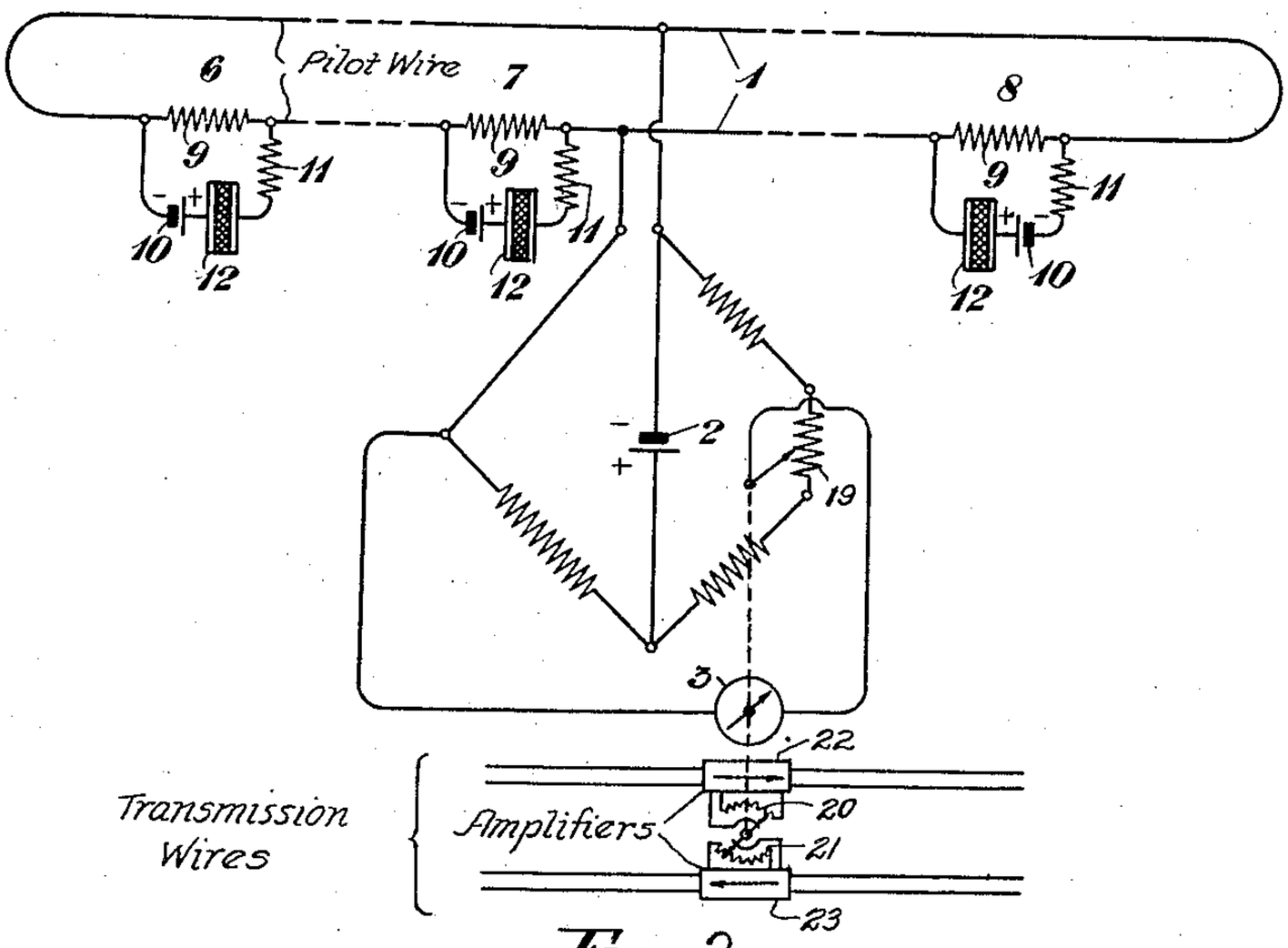

Fig. 2

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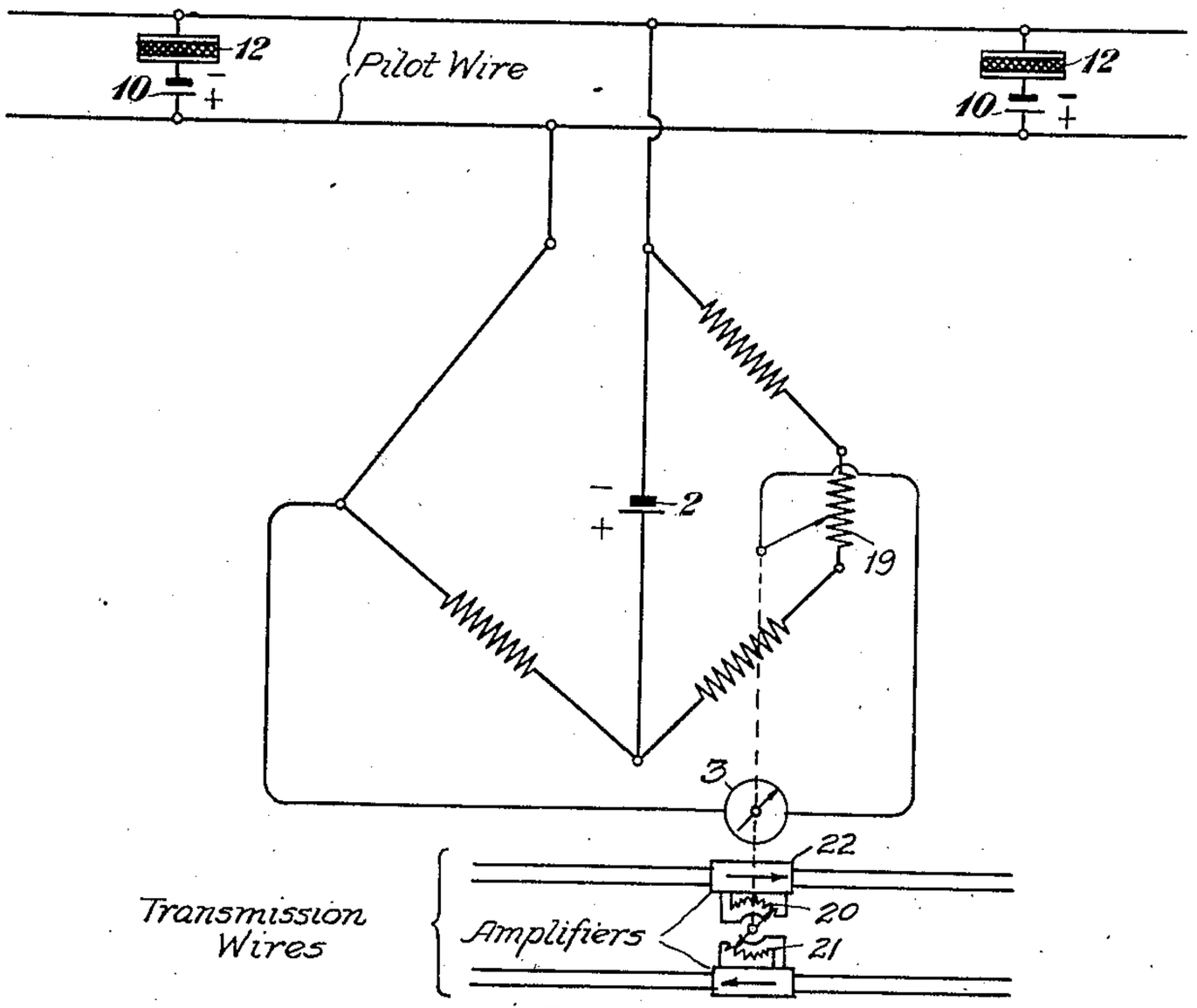

Fig. 3

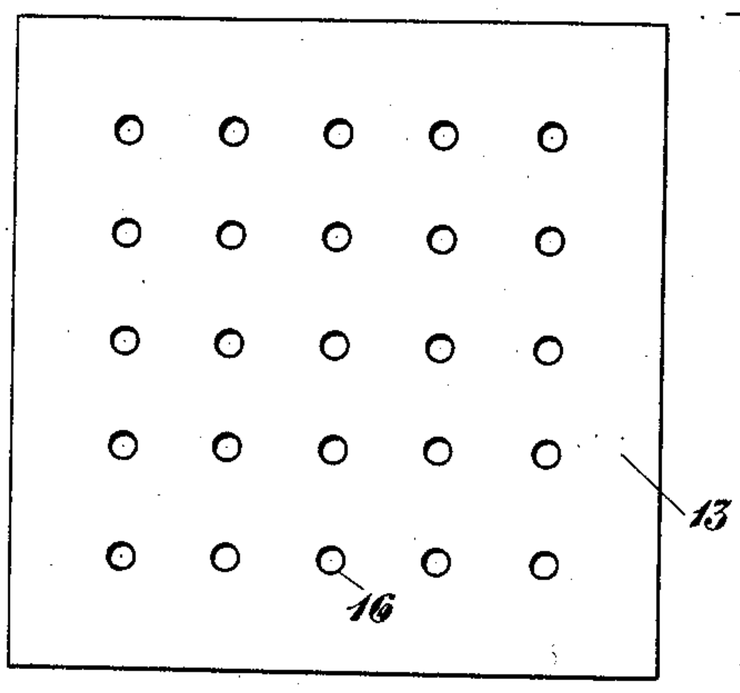

Fig. 4

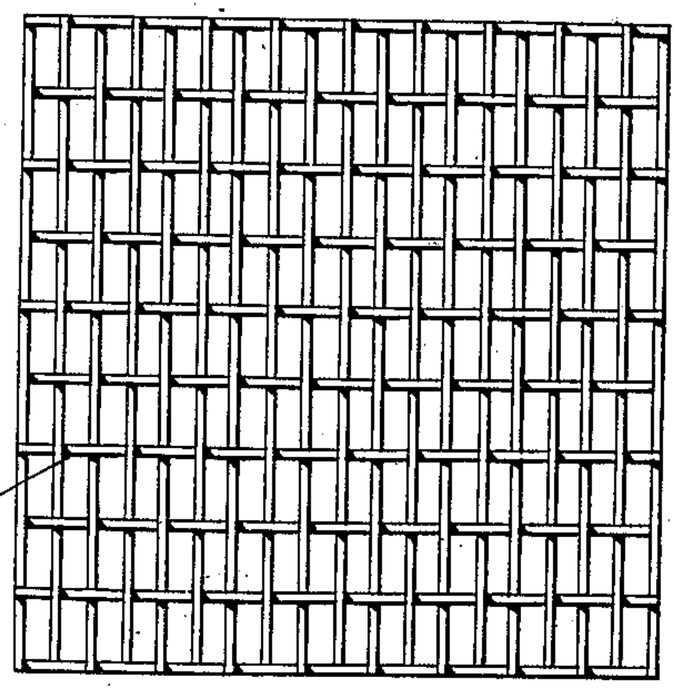

Fig. 6

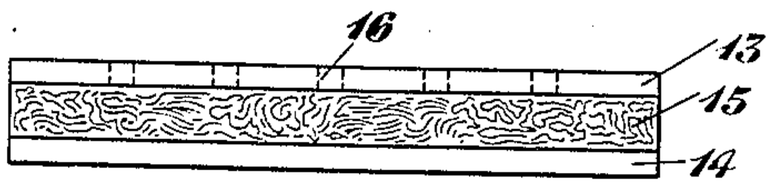

Fig. 5

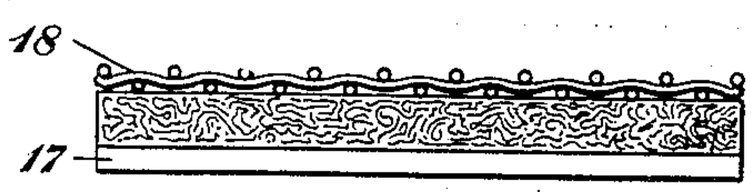

Fig. 7

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UNITED STATES PATENT OFFICE.

HARRY NYQUIST, OF ELMHURST, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

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

Application filed February 19, 1923. Serial No. 620,094.

This invention relates to electric transmission circuits and more particularly to long repeatered electric transmission circuits.

The object of the invention is to provide suitable methods of and means for maintaining substantially constant the transmission equivalent of electric circuits in spite of the effect upon such circuits of variations in humidity.

It is well understood by those skilled in the art that varying humidity conditions cause variations of the leakage between the conductors of these transmission circuits. For the purpose of compensating for the effects of the humidity variations applicant provides an auxiliary circuit including one or more members whose conductivity increases or decreases with an increase or a decrease, respectively, of the humidity, an indicating device responsive to such changes in the conductance of the auxiliary circuit, and means for automatically regulating the gain of the repeaters in the transmission circuits in accordance with the indications of the above mentioned device.

It is proposed to show three desirable arrangements embodying applicant's invention by way of specific illustration. In each arrangement, the member upon which the humidity acts directly is placed so as to provide, in combination with the other elements of the arrangement, the desired compensation for the effects of the varying humidity conditions. Thereafter, there will be shown by way of illustration two desirable constructions of the peculiar member.

United States Patent No. 1,438,219, granted to Alva B. Clark, covers methods of and means for taking care of the effects of temperature variations on the transmission circuits. One desirable embodiment of applicant's invention is a modification of the system described in the above numbered patent, whereby the gain of the repeaters may be varied to compensate for the effects of humidity variations—without seriously affecting the ability of the system to take care of the temperature variations. Briefly, Clark's means for taking care of temperature variation are disclosed as consisting essentially of a balance bridge, of which a pilot wire in the cable forms one arm, a battery connected across said bridge, a galvanometer so connected as to give the desired indications, and means for varying the gain of the repeaters in the transmission circuits. An increase or a decrease in the resistance of the pilot wire, caused by a change of temperature, results in the unbalancing of the bridge, which unbalancing operates through the means indicated above and briefly described below to vary the gain of the repeaters in the transmission circuits, thereby compensating for the effect upon the given circuit of the change in temperature. Applicant introduces an additional member in one arm of the balance bridge, as fully disclosed below, this member being so constructed and so placed as to provide compensation for the changes in humidity, thus serving to maintain substantially constant the transmission equivalent of the transmission circuits in spite of the humidity variation.

A second desirable arrangement of applicant's system, based upon the same general principle as the first and including, like the first, a pilot wire, a balance bridge, and means for regulating the repeaters upon the unbalancing of the bridge, has the added advantage of providing compensation for the humidity variations at different points in the circuits, which end is attained by the introduction at each office of an auxiliary network connected in series with the pilot wire and including a member directly responsive to humidity changes.

In a third desirable arrangement, which is a modification of the second, a directly responsive member is connected across the two line wires of the auxiliary circuit at each office.

Applicant's invention will be more clearly understood when the following detailed description is read in connection with the accompanying drawing. Figure 1 of the drawing shows schematically the essential features of the first desirable arrangement, while Figs. 2 and 3 show in like manner the second and third desirable arrangements respectively. Fig. 4 shows a plan view and Fig. 5 a side elevation of one desirable construction of the peculiar member referred to above, while Figs. 6 and 7 show similar views, respectively, of a second desirable

construction of the same member. Like numerals of reference in Figs. 1, 2 and 3 designate corresponding parts.

With particular reference to Fig. 1, the pilot wire 1 forms one arm of a balance bridge, 2 is the battery connected across the bridge, and 3 is the galvanometer. An arm of the bridge adjacent to the above mentioned arm comprises two parts in parallel, one part being simply a resistance 4, the other consisting of a resistance 5 and a member 12. This member 12 is so constructed that its conductivity increases with the increase in humidity to approximately the same degree as the conductivity of the cabling affected by such humidity increase. Two desirable constructions of this member are described in detail below. As the humidity increases and, consequently, the conductance of the member 12 increases, the balance bridge is unbalanced in the same direction as it would be if the resistance of the pilot wire 1 were increased. In balancing, the bridge will increase the gain of the repeaters through mechanical means, as specifically described in the above numbered Clark patent. Briefly, this operation and the apparatus involved therein are described as follows: 19 indicates an adjustable resistance corresponding to resistance R_6 of the above numbered Clark patent, this resistance being automatically adjusted in the manner indicated in the said Clark patent, that is, when the galvanometer is deflected, the resistance is adjusted in accordance with the deflection of the galvanometer by mechanical means so as to balance the bridge. As indicated in the above numbered Clark patent, the mechanical movement utilized to balance the bridge is also utilized to produce a corresponding change in the setting of the potentiometers 20 and 21 (corresponding to P_3 and P_4 of the above numbered Clark patent), the setting of these potentiometers controlling the amplification of amplifiers 22 and 23 of the transmission circuits, respectively, these amplifiers (which correspond to amplifiers A_3 and A_4 of the above numbered Clark patent) being shown symbolically. Thus, there is effected a suitable change in the gain of the repeaters of the transmission circuits.

With particular reference to Fig. 2, there is represented, as in Fig. 1, a pilot wire 1, forming one arm of the balance bridge, a battery 2, and a galvanometer 3. Three offices, representative of any number of offices, are indicated as 6, 7 and 8, these offices being subject to different humidity conditions. At each office there is introduced in series with the pilot wire 1 an auxiliary network including two parts in parallel. The one part is simply a series resistance 9. The other part is made up of a battery 10, a resistance 11, and a member 12 similar to the member 12 described generally in connection with Fig. 1. This network operates as follows: (1) In dry weather, practically no current passes through the member 12, and consequently only the series resistance 9 is effective. (2) As the humidity increases, the member 12 becomes conductive, and as a result current flows through the shunt element of the network. In the absence of the battery 10 this would have the same effect on the bridge that a decrease in the resistance of the pilot wire would have. This change in the balance of the bridge would be roughly proportional to the decrease in transmission of the circuits affected by the increase in humidity. Since the mechanism controlled by the bridge is designed primarily to increase the gain as the resistance increases with the temperature, and vice versa, the change mentioned above would be in such a direction as to decrease the gain of the repeaters. It is therefore necessary to provide some means for translating the unbalancing effect of the network into an effective unbalance in a direction opposite to that indicated above. For this purpose the batteries 10 are included in the shunt elements of the networks. The poling of the batteries 10 is to be noted. As indicated in the drawing, these batteries are poled in such a manner as to tend to cause a flow of current in the pilot wire in a direction opposite to that caused by the battery connected across the bridge. This produces an effect equivalent to an increase of resistance in the pilot wire. The result is the same as that mentioned in connection with Fig. 1, viz, an increase in the gain of the repeaters.

With particular reference to Fig. 3, at each of two offices, representative of any number of offices, there are connected across the two line wires of the auxiliary circuit a member 12 similar to the member 12 described generally in connection with Fig. 1, and a battery 10. As the humidity increases, the member 12 becomes conductive, and a current is caused to flow in the line wires—with the results described above.

Figs. 4 and 5 show diagrammatically one desirable construction of the member labelled 12 in Figs. 1, 2 and 3. Two metal plates 13 and 14 form the terminals of the member. Between these two plates there is placed a layer of cotton 15, into which may be introduced hygroscopic salts. The plate 13 is perforated, as at 16. As is well known, cotton is hygroscopic and becomes conductive when exposed to air of considerable humidity. By the introduction of hygroscopic salts, the effect of a change of humidity on the conductance of the member 12 can be further regulated and brought to the exact point desired in connection with any given circuit.

Figs. 6 and 7 represent a second desirable

construction of the member 12 of Figs. 1, 2 and 3. A metal plate 17 corresponds to the plate 14 of Fig. 5 and constitutes one terminal of the member. Forming the other terminal is a layer of wire gauze 18. The layer between the plate 17 and this upper layer of wire gauze is as described in connection with Figs. 4 and 5.

What is claimed is:—

1. In a system comprising a plurality of electric circuits subject to similar atmospheric conditions and a balance bridge associated with one of said circuits, the method of compensating for the effect on the transmission equivalent of the circuits of different humidity variations at a plurality of points in the system, which consists in causing the humidity changes at the different points to produce jointly an unbalancing of the balance bridge associated with the one circuit, and causing the rebalancing of the bridge to produce compensating adjustments of elements of the other circuits.

2. In a system comprising a plurality of electric circuits subject to similar atmospheric conditions, a balance bridge associated with one of the circuits, and amplifying means in each of the other circuits; the method of compensating for the effect on the transmission equivalent of the circuits of different humidity variations at a plurality of points in the system, which consists in causing the humidity changes at the different points to produce jointly an unbalancing of the balance bridge associated with the one circuit, and causing the rebalancing of the bridge to produce compensating changes in the amplification of the amplifying means in the other circuits.

3. In a signaling system, a plurality of transmission circuits subject to similar atmospheric conditions, means associated with one of said circuits at a plurality of points thereon and adapted to change the electrical characteristics thereof in response to local humidity changes, means associated with said circuit and responsive to changes in the electrical characteristics thereof, and means controlled by said latter responsive means for adjusting the transmission equivalent of the other circuits.

4. In a signaling system, a plurality of transmission circuits, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot circuit at a plurality of points thereon and adapted to change the electrical characteristics thereof in response to local humidity changes, means associated with said pilot circuit and responsive to variations in the electrical characteristics thereof, and means for varying the electrical characteristics of said transmission circuits under the control of said latter responsive means.

5. In a signaling system, a plurality of transmission circuits, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot circuit at a plurality of points thereon and adapted to change the electrical condition thereof in response to local humidity changes, a switch, means for automatically setting said switch in accordance with the electrical condition of said pilot circuit, and means controlled by said switch for adjusting the transmission efficiency of said transmission circuits.

6. In a signaling system, a plurality of transmission circuits, amplifying means for said circuits, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot circuit at a plurality of points thereon and adapted to change the electrical condition thereof in response to local humidity changes, a switch, means for automatically setting said switch in accordance with the electrical condition of said pilot circuit, and means controlled by the setting of said switch for adjusting the amplification of said amplifying means.

7. In a signaling system, a plurality of transmission circuits, a pilot wire subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot wire at a plurality of points thereon and adapted to change the current flow therethrough in response to local humidity changes, a balance bridge, said pilot wire being included in one arm of said balance bridge, a switch, means for automatically setting said switch in accordance with the current flow in said balance bridge, and means controlled in accordance with the setting of said switch for adjusting the transmission efficiency of said transmission circuits.

8. In a signaling system, a plurality of transmission circuits and a pilot circuit, the conductors of all said circuits being subject to similar humidity variations, means associated with said pilot circuit at a plurality of points thereon and adapted to change the electrical characteristics thereof in response to local humidity changes, means responsive to changes in the electrical characteristics of the pilot circuit due to humidity changes, and means controlled by said latter responsive means for adjusting the transmission equivalent of the transmission circuits.

9. In a signaling system, a plurality of transmission circuits and a pilot circuit, the conductors of all said circuits being subject to similar humidity variations, means associated with said pilot circuit at a plurality of points thereon and adapted to change the electrical characteristics thereof in response to local humidity changes, an automatic

switch, means responsive to changes in the electrical characteristics of the pilot circuit due to humidity changes for variably setting said switch, and means controlled by the setting of said switch for adjusting the transmission efficiency of the transmission circuits.

10. As means for compensating for the effect of humidity variations on the transmission equivalent of repeatered transmission circuits, a pilot wire, a balance bridge including said pilot wire as one of its arms, an auxiliary network in the pilot wire circuit at each office of the system, said network including a battery and a member whose conductivity varies with humidity, a current indicating device responsive to changes in the electrical characteristics of the bridge, and a device designed to vary the gain of the repeaters in response to the current in, and in accordance with the indications of, said current indicating device.

11. As means for compensating for the effect of humidity variations on the transmission equivalent of repeatered transmission circuits, a pilot wire; a balance bridge including said pilot wire as one of its arms; a battery connected across said bridge, an auxiliary network introduced in series with the pilot wire at each office of the system, said network including two parts, the first part consisting of a resistance, and the second part comprising a resistance, a member whose conductivity varies with humidity, and a battery, said battery being poled so as to cause a flow of current in the pilot wire opposite in direction to that caused by the battery connected across the bridge; a current indicating device responsive to changes in the electrical characteristics of the bridge; and a device designed to vary the gain of the repeaters in response to current in, and in accordance with the indications of, said current indicating device.

12. As means for compensating for the effect of humidity variations on the transmission equivalent of repeatered transmission circuits, a pilot wire; a balance bridge including said pilot wire as one of its arms; an auxiliary network in the pilot wire circuit at each office of the system, said network including a battery and a member comprising two conductive terminals, one of said terminals being perforated, and an intermediate layer of material whose conductivity varies with humidity; a current indicating device responsive to changes in the electrical characteristics of the bridge; and a device designed to vary the gain of the repeaters in response to current in, and in accordance with the indications of, said current indicating device.

13. As means for compensating for the effect of humidity variations on the transmission equivalent of repeatered transmission circuits, a pilot wire; a balance bridge including said pilot wire as one of its arms; a battery connected across said bridge; an auxiliary network introduced in series with the pilot wire at each office of the system, said network including two parts, the first part consisting of a resistance, and the second part comprising a resistance, a member comprising two conductive terminals, one of said terminals being perforated and an intermediate layer of material whose conductivity varies with humidity, and a battery, said battery being poled so as to cause a flow of current in the pilot wire opposite in direction to that caused by the battery connected across the bridge; a current indicating device responsive to changes in the electrical characteristics of the bridge; and a device designed to vary the gain of the repeaters in response to current in, and in accordance with the indications of, said current indicating device.

14. In a signaling system in which the transmission equivalent of repeatered transmission circuits is maintained substantially constant in spite of charges in the resistance of such circuits, due to atmospheric changes, by causing the changes of resistance in a pilot wire to unbalance a balance bridge including said pilot wire as one of its arms, said bridge, in balancing, operating by mechanical means to vary the gain of the repeaters in the transmission circuits; means for compensating for variations in leakage between the conductors, due to humidity changes, said means comprising an auxiliary network introduced in series with the pilot wire at each office affected by the humidity changes, said network including two parts, the first part consisting of a resistance, and the second part comprising a resistance, a member whose conductivity varies with humidity, and a battery, said battery being poled so as to cause a flow of current in the pilot wire opposite in direction to that caused by the battery connected across the bridge.

15. In a signaling system in which the transmission equivalent of repeatered transmission circuits is maintained substantially constant in spite of changes in the resistance of such circuits, due to atmospheric changes, by causing the changes of resistance in a pilot wire to unbalance a balance bridge including said pilot wire as one of its arms, said bridge, in balancing, operating by mechanical means to vary the gain of the repeaters in the transmission circuits; means for compensating for variations in leakage between the conductors, due to humidity changes, said means comprising an auxiliary network introduced in series with the pilot wire at each office affected by the humidity changes, said network including two parts, the first part consisting of a resistance, and the second part comprising a resistance, a battery poled so as to cause a flow of current

in the pilot wire opposite in direction to that caused by the battery connected across the bridge, and a member comprising two conductive terminals, one of said terminals being perforated and an intermediate layer of material whose conductivity varies in proportion to the variation of humidity.

16. In a signaling system, a plurality of transmission circuits subject to similar conditions, means associated with one of the circuits and adapted to change the electrical characteristics thereof in response to humidity variation, means associated with said circuit and responsive to changes in the electrical characteristics thereof, and means controlled by said latter responsive means for adjusting the transmission equivalent of the other circuits.

17. In a signaling system, a plurality of transmission circuits, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot circuit and adapted to change the electrical characteristics thereof in response to humidity variation, means associated with said pilot circuit and responsive to variations in the electrical characteristics thereof, and means for varying the electrical characteristics of said transmission circuits under the control of said latter responsive means.

18. In a signaling system, a plurality of transmission circuits, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot circuit and adapted to change the electrical condition thereof in response to humidity variation, a switch, means for automatically setting said switch in accordance with the electrical condition of said pilot circuit, and means controlled by said switch for adjusting the transmission efficiency of said transmission circuits.

19. In a signaling system, a plurality of transmission circuits, amplifying means in said circuits, a pilot circuit subject to influences similar to those affecting the transmission efficiency of said transmission circuits, means associated with said pilot circuit and adapted to change the electrical condition thereof in response to humidity variation, a switch, means for automatically setting said switch in accordance with the electrical condition of the pilot circuit, and means controlled by the setting of said switch for adjusting the amplification of said amplifying means.

20. In a signaling system, a plurality of transmission circuits and a pilot circuit, the conductors of all said circuits being subject to similar humidity variations, means associated with said pilot circuit and adapted to change the electrical characteristics thereof in response to humidity variation, means responsive to changes in the electrical characteristics of the pilot circuit due to humidity changes, and means controlled by said latter responsive means for adjusting the transmission equivalent of the transmission circuits.

21. In a signaling system, a plurality of transmission circuits and a pilot circuit, the conductors of all said circuits being subject to similar humidity variations, means associated with said pilot circuit and adapted to change the electrical characteristics thereof in response to humidity variation, an automatic switch, means responsive to changes in the electrical characteristics of the pilot circuit due to humidity changes for variably setting said switch, and means controlled by the setting of said switch for adjusting the transmission efficiency of the transmission circuits.

In testimony whereof, I have signed my name to this specification this 16th day of February, 1923.

HARRY NYQUIST.