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ELECTRICAL TESTING SYSTEM

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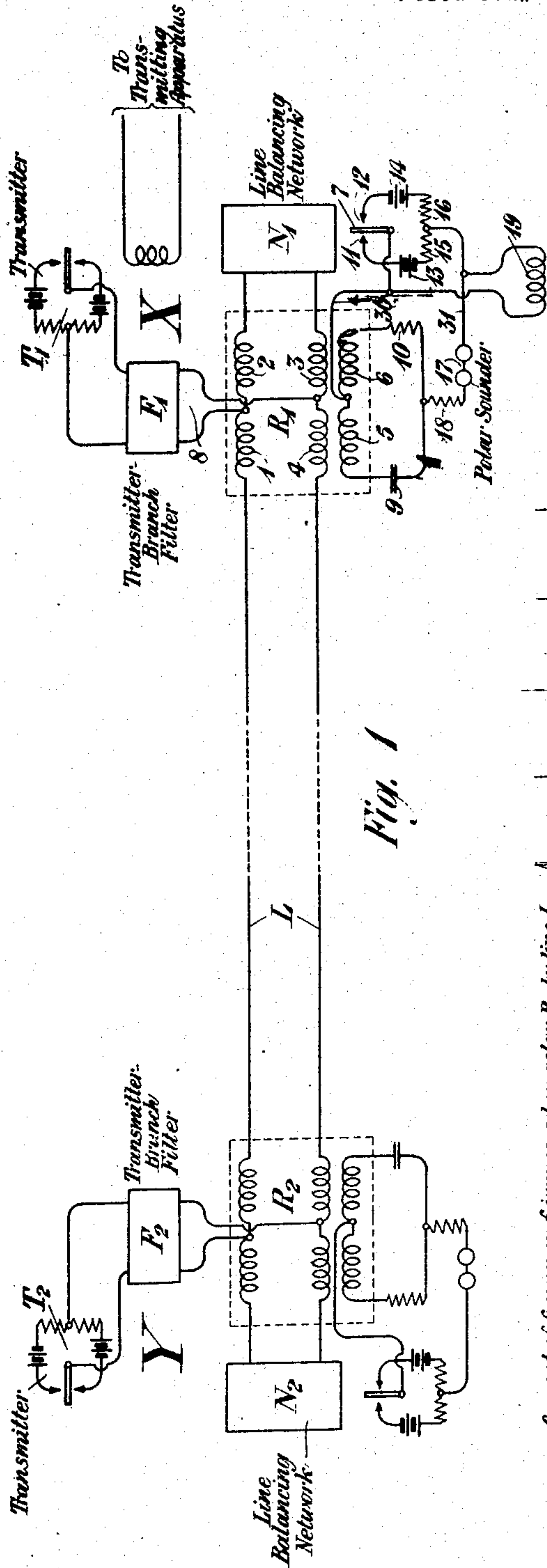


Fig. 1

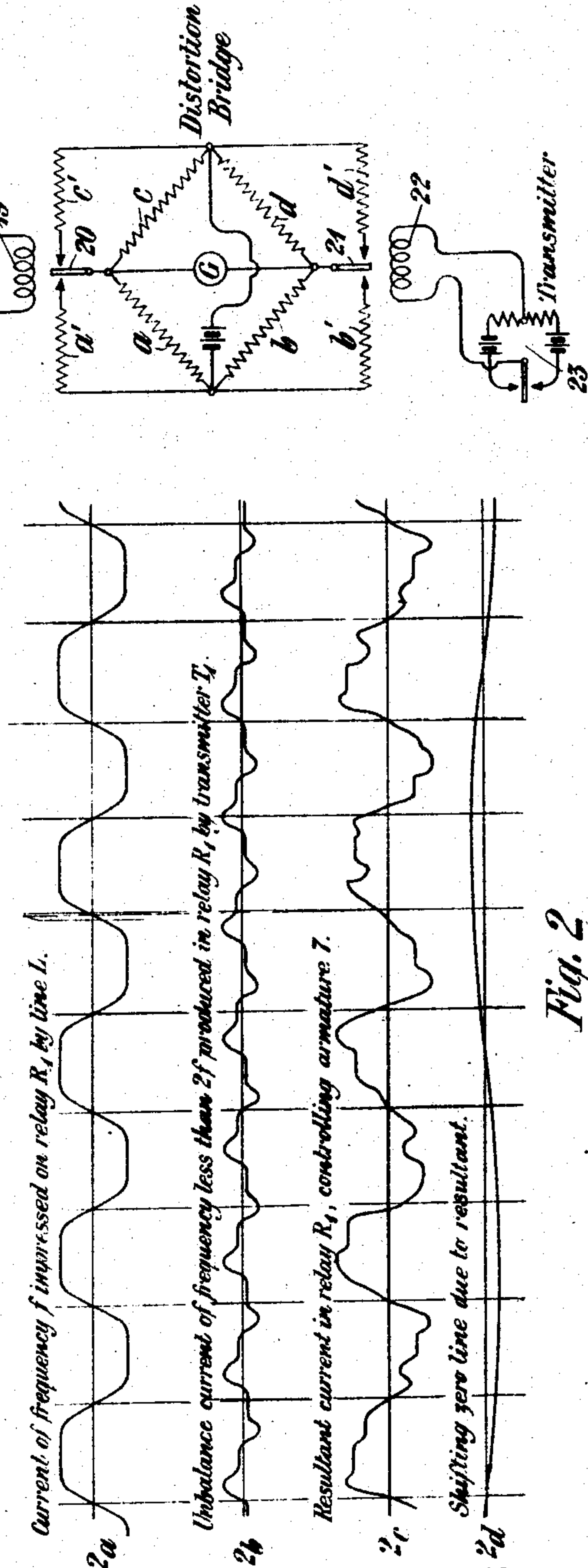


Fig. 2

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ELECTRICAL TESTING SYSTEM.

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To all whom it may concern:

Be it known that I, HARRY NYQUIST, residing at Elmhurst, in the county of Queens and State of New York, have invented certain Improvements in Electrical Testing Systems, of which the following is a specification.

This invention relates to electrical testing systems and particularly to an arrangement for determining the degree of unbalance between two networks, such as a signaling circuit and the network designed to balance the said circuit.

In order to operate most efficiently certain types of signaling circuits, as, for example telephone repeater circuits and duplex telegraph circuits, it is necessary to maintain a high degree of balance between the line circuit and the network which is intended to balance the said circuit.

To attain this result, it is necessary to determine the degree of unbalance between a line circuit and its balancing network. An arrangement for determining the unbalance between a line and its network in a telephone repeater circuit is shown in the patent of Clark and Crisson, No. 1,407,983, granted Feb. 28, 1922. This provides for the determination of the degree of unbalance by applying sinusoidal waves of different frequencies, preferably throughout the voice range, and determining the unbalance at each frequency. Such a method of measuring is desirable in telephony because we are there concerned with the steady-state condition, but, in telegraphy the transient phenomena are of greater concern.

A telegraph signaling impulse is a steep sloped wave comprising a plurality of different frequencies which are simultaneously impressed upon the line circuit whenever the key of the transmitting device is closed. It will accordingly be seen that in telegraphy the transient phenomena are of prime importance, and consequently, a measurement made by a sinusoidal wave of a definite frequency does not give correct results.

It is well known to those familiar with the art of duplex telegraphy that if unbalance exists between a line circuit and a network

which is designed to simulate electrically the said circuit, the application of signaling impulses to the line circuit by the transmitter connected with the terminal circuit at one end of the said line circuit will cause the receiving relay connected with the same terminal circuit to respond to the transmitted signals, the degree of response depending upon the amount of unbalance existing between the line circuit and its balancing network. This reaction of the transmitted signals upon the receiving relay, due to unbalance between the line and its network, causes distortion of the telegraph signals received from the distant transmitting circuit, the distortion manifesting itself in lengthening or shortening the received signal impulses.

The object of this invention is broadly to determine the degree of unbalance between a line circuit and its artificial line by the application thereto of telegraph signaling impulses, whereby the unbalance may be determined by the transient effects rather than by the steady-state conditions. Another object of this invention is to facilitate the adjustment of the network so that the receiving relay will be affected to the minimum extent by the transmission of signals from that end of the circuit at which the relay is located.

Although this invention will be described in connection with a metallic duplex telegraph circuit, it is to be understood that it is not limited to this particular type of circuit, but is capable of measuring unbalances existing between any two types of networks.

This invention will be better understood from the following description when read in connection with the attached drawing of which Figure 1 shows one form of embodiment of the invention and Fig. 2 shows the current curves 2^a , 2^b , 2^c , and 2^d , which serve to make clear the principle upon which the invention rests.

In Fig. 1 a line circuit L extends between two stations X and Y. Connected with the line L at the station X is a balancing network N_1 the function of which is to balance the said line with respect to the transmission of signaling impulses by the transmitter T_1 . Connected between the line L and its net-

work N_1 is a receiving relay R_1 , having a plurality of windings designated 1, 2, 3, 4, 5 and 6. Windings 1, 2, 3 and 4 are of the same magnitude and are connected serially in the line. Windings 5 and 6 are connected in series with what is commonly known as the vibratory circuit. All of these windings are arranged upon the same core, the magnetomotive force of which is adapted to control the action of armature 7 of the receiving relay.

Bridged across the junction point of windings 1 and 2, and the junction point of windings 3 and 4 is the transmitting circuit 8, by means of which signaling impulses from the transmitter T_1 are effectively applied to the line L for transmission to the receiving circuit at the distant station Y . This transmitting circuit comprises in addition to the transmitter T_1 a transmitter-branch filter F_1 which is adapted to modify the impulses generated by the transmitter T_1 so that they will have a wave shape which is best adapted to produce an arrival wave of the most desirable form at station Y , and at the same time to prevent interference with the telephone signaling currents which might be transmitted simultaneously over the circuit L .

It will be clearly seen that the current impressed by the transmitting circuit 8 will flow in opposite directions in windings 1 and 2, and also oppositely in windings 3 and 4, and if the network N_1 exactly balances the line L , the current will likewise be of the same magnitude in the respective windings so that no resultant flux will be set up on the core and consequently no effect will be produced upon the armature 7. If, however, there exists an unbalance between the network N_1 and its line L , the magnitude of the currents in the network and the line will be different, thereby affecting the armature 7. The object of this invention is to determine the degree of unbalance that exists between the network and its line and to eliminate or reduce the unbalance by proper adjustment.

The vibratory circuit, in which the windings 5 and 6 are located, also contains a condenser 9 and a resistance 10, the function of which will later be made clear in the description of the operation of the circuit. Bridged symmetrically across the vibratory circuit, between the junction point of windings 5 and 6, and the junction point between condenser 9 and resistance 10 is a circuit containing the armature 7 and its associated apparatus. The armature 7 which is connected by conductor 30 with the midpoint of windings 5—6, is adapted to move between contacts 11 and 12, with which are connected batteries 13 and 14 of opposite polarity. Connected between the batteries 13 and 14 are the resistances 15 and 16, the

junction point of which is connected by conductor 31 with the polar sounder 17 and through the resistance 18 to the vibratory circuit at the junction point between condenser 9 and resistance 10.

The terminal circuit at station Y is similar to the circuit at station X as described above and needs no further explanation.

Bridged across the conductors 30 and 31 is the winding 19, which is adapted to control the movement of the armature 20 connected to one of the corners of the distortion bridge, which is of the type shown and described in the patent to Nyquist 1,435,328, dated November 14, 1922. Connected with the correspondingly opposite corner of the said bridge is another armature 21, the movements of which are controlled by the flow of current in the winding 22 which is connected with a transmitting device 23, designed to be operated in synchronism with the transmitter T_2 at station Y except that it operates with a lag which is made substantially equal to the lag produced by the telegraph system. This bridge is so designed that when the armatures 20 and 21 are in the position shown in the drawing, or when the armatures are upon corresponding contacts, that is to say, when armatures 20 and 21 are upon contacts of A' and B' respectively, or upon contacts of C' and D' respectively, the bridge remains balanced and no current will flow through the path containing the galvanometer G . If, however, one of the armatures is in its neutral position and the other armature has closed either one of its contacts, or if the said armatures are upon oppositely disposed contacts the bridge will be unbalanced and the magnitude of the unbalancing current will be indicated by the galvanometer.

Having in mind the foregoing description of the apparatus shown in the drawing, the invention will be clearly understood from the following description of the mode of operation of the circuit in which it is embodied.

This invention is based upon the principle of "beating" together two waves, each comprising a series of reversals of two different frequencies and detecting the variations in the operation of the armature of the receiving relay resulting from the effect of unbalance between the line circuit and its balancing network. Let it be assumed that reversals of a frequency f are being transmitted by the transmitter T_2 over the line L so as to operate the armature 7 of the receiving relay and that no signals are being transmitted by T_1 . When the current from the transmitter T_2 flows through the windings 1—2 and 3—4 in a definite direction, it will move the armature 7 to one of its contacts, as for example, 12. Current will then flow from battery 14 through contact

12 to the junction point of windings 5—6 and through the resistances 10 and 18 and the polar sounder 17 and resistance 16 to the opposite side of the battery. This will charge the condenser 9, located in the vibratory circuit. Furthermore, the flow of current through the winding 6 will be in such direction as to create a magneto-motive force which will have such effect upon the armature 7 as to tend to pull it away from the contact 12, although it will not affect the actual opening of this contact so long as the line current from the transmitter T_2 tends to flow in the previously assumed direction through the line windings of the relay R_1 . When the line current through the windings 1—2 and 3—4, falls below a certain minimum value the condenser 9 will discharge through a circuit comprising the windings 5 and 6 in series with the resistance 10, and the resultant discharge of current through these windings will be in such direction as to move the armature 7 quickly from contact 12. Since it has been assumed that the wave being transmitted by the transmitter T_2 constitute a series of reversals of frequency f , such as shown by curve 2^a , the reversal of the current on the line L and in the windings 1—2 and 3—4 will move the armature to contact 11 and will cause current of positive polarity to flow through the vibratory circuit, charging the condenser 9 in an opposite sense. The flow of current through the winding 6 will be in a direction as will tend to cause the armature 7 to move away from contact 11 and this will be affected by the action of the discharge of condenser 9 through the windings 5 and 6, as soon as the current in the line windings falls below a definite minimum amount. The purpose of this vibratory circuit is to overcome the sluggish action of the armature 7 when the current in the line circuit reverses, as in the sending of marking and spacing signals, and provides therefor a means for obtaining quick positive action of the receiving relay. Therefore the receipt of a series of reversals of frequency f_1 as represented by curve 2^a , will cause uniform operation of the receiving relay.

Now, assume that while the transmitter T_2 at station Y is being operated to send over the line L reversals of frequency f , the transmitter T_1 is simultaneously operated for the purpose of transmitting from station X to station Y , a series of current reversals of frequency f' which may be either slightly greater or less than twice the frequency f of the signals sent over the line L by the transmitter T_2 . The current from the transmitter T_1 is impressed by the transmitting circuit 8 across the line L at the junction points between the windings 1—2 and the windings 3—4. This current divides, part of it flowing through the wind-

ing 1 over the line L and back through the winding 4, and the other part flowing through the winding 2 through the line balancing network N_1 and the winding 3. Since these windings are upon the same core, and since the flow of current is in opposite directions from their respective junction points there will be no resulting magnetization of the core if the currents are equal, which means if the line balancing network exactly balances the line L . If, however, there exists an unbalance between the line balancing network and the line circuit, the currents flowing in the windings 1—2 and 3—4 from their respective junction points, will be unequal and the resultant magnetization will cause a movement of the armature 7. The wave shown in curve 2^b represents the unbalance current that tends to magnetize the core of the relay R_1 and therefore to operate the armature 7, and has, for example, been assumed to be slightly less than 2^f . It is the difference in the current that flows from the midpoint of the windings R_1 through the line and through the line balancing network N_1 . This resultant current, due to the inequality of balance, either adds to or subtracts from the incoming wave of frequency f and produces a resultant magnetizing current as shown in curve 2^c . It will be seen that the wave shown in curve 2^c does not cross the zero axis at definite intervals of time, but that some of the reversals have been shortened and others have been lengthened. This distortion of the magnetizing current which is produced by the unbalance between the line circuit and the balancing network likewise produces irregularity of operation of the armature 7. The armature will not remain upon its contacts for equal periods of time since the time that it will remain upon any one contact will depend upon the duration of the magnetizing current.

The impulses resulting from the action of the armature will be impressed upon the winding 19 which controls the armature 20 connected with one of the corners of the distortion bridge. Simultaneously with the application of current to the winding 19 there will be impressed upon the winding 22 a current wave of the same magnitude and phase as shown in curve 2^a , which is the curve of the current set up by the transmitter T_2 as corrected for the lag due to transmission over the line. The currents in the windings 19 and 22 will cause their corresponding armatures to touch their right-hand or left-hand contact points, depending upon the direction of flow of current through the windings. If the currents in the two windings were identical in phase and magnitude, the positions of the armatures 20 and 21 would at all times correspond, that is to say, that at any instant of

time both armatures would be on their right-hand contacts or their left-hand contacts, or in the neutral position between the contacts. Since, however, the current arriving over the line L from the transmitter T_2 has superimposed thereon the unbalance current of the transmitter T_1 , which exists by virtue of the unbalance between the line and its balancing network, the current flowing in the winding 19 will not be in the same phase as the current flowing through the winding 22 and consequently the movement of the armature 20 will not be in synchronism with the movement of the armature 21. The movement of the armature 20 into contact with either of its contact points in advance of the time when the armature 21 comes into contact with the corresponding contact point will produce on unbalance in the bridge network, which unbalance will be indicated by the movement of the needle of the galvanometer G. Adjustments are then made on the artificial line while observing the periodic change in the reading given by the distortion bridge galvanometer needle. This adjustment is continued until the needle indicates the minimum variation throughout a definite period of time which indicates the minimum unbalance between the lines and its balancing network.

It will be seen that the method of determining the degree of unbalance between two networks comprises the simultaneous impression of two periodic signaling waves upon a relay, the frequency of one of the signaling waves being slightly greater or less than double the frequency of the other signaling wave, and allowing the resultant magnetizing current to control the operation of the armature of the relay, the frequency of operation of which closely follows the frequency of the combined waves. By impressing the impulses resulting from the action of the armature upon one of the windings of the distortion bridge, as shown in my application, Serial No. 353,416 filed January 23, 1920, and simultaneously impressing upon another winding of the distortion bridge a wave having the same frequency and shape as the lower frequency signaling wave, the extent of the unbalance between the line network and the line circuit may be determined, and the line network may be adjusted until the point of minimum unbalance is obtained.

Although this invention has been disclosed as having a definite form and arrangement of parts it is to be understood that it is capable of embodiment in other and different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In an electrical testing system, the method for determining the degree of un-

balance between two networks, which consists in simultaneously transmitting and receiving telegraph signals of different frequencies, and indicating the distortion of the received signals by the transmitted signals.

2. In an electrical testing system, the method for determining the degree of unbalance between a line circuit and its balancing circuit, which consists in simultaneously receiving and transmitting telegraph signals, the respective signals being of different frequencies, allowing the said signals to actuate a signal receiving device, and indicating the distortion of the received signals by the transmitted signals due to unbalance between the line circuit and its balancing circuit.

3. In an electrical testing system, the method for determining the degree of unbalance between two electrical networks, which consists in impressing signaling impulses of different frequencies from separate sources upon the said networks, allowing the impulses from one of said sources to interfere with the impulses from the other of the said sources in proportion to the degree of unbalance between the two networks, and determining the degree of unbalance by virtue of the degree of distortion produced in the impulses from the other of said sources.

4. In an electrical testing system, the method for determining the degree of unbalance between two electrical networks, which consists in creating signaling impulses of different frequencies, impressing said impulses of different frequencies simultaneously upon the said networks, beating together the said frequencies, and determining the degree of unbalance between the said networks by virtue of the beat frequency produced.

5. In an electrical testing system, the method for determining the degree of unbalance between two electrical networks, which consists in creating signaling impulses of different frequencies impressing said impulses simultaneously upon the said networks, beating together the said frequencies, and allowing the resultant frequency to control an indicating device whereby the degree of distortion resulting from unbalance between the said networks may be determined.

6. In a duplex telegraph signaling system characterized by a plurality of transmitting circuits, a line circuit connecting said transmitting circuits, a balancing circuit, a receiving circuit having distortion indicating means associated therewith, and means for electrically relating the said balancing circuit and receiving circuit with the said line circuit and one of said transmitting circuits, the method for determining the degree of unbalance between the line circuit and its bal-

ancing circuit, which consists of impressing simultaneously across the said line circuit at opposite ends thereof telegraph signals of different frequencies, beating together the signals of the said frequencies and comparing the resultant frequency with that impressed upon the said line circuit at the distant end thereof whereby the degree of unbalance between the line circuit and the balancing circuit may be determined.

7. The method for detecting unbalance between two electrical networks, which consists in impressing across the said networks telegraph signaling impulses of different frequencies, and detecting the unbalance between the said networks by the effect produced in a receiving circuit.

8. The method for detecting unbalance between two electrical networks, which consists in impressing across the said networks telegraph signaling impulses of different frequencies, and detecting the unbalance between said networks by an indicating device in a receiving circuit coupled to the said networks.

9. In a duplex telegraph signaling system, the combination with a line circuit of a plurality of terminal circuits, each comprising a transmitting circuit adjusted to transmit signals of different frequencies, a receiving circuit, a network adapted to balance the said line circuit, and a relay having a plurality of windings for electrically connecting the said circuits, and a distortion bridge circuit connected with a receiving circuit of one of the said terminal circuits for determining the magnitude of the unbalance between the line circuit and the balancing network associated with the said latter terminal circuit.

10. In a duplex telegraph signaling system, the combination with a line circuit of a plurality of terminal circuits each comprising a transmitting circuit, a receiving circuit, a network adapted to balance the said line circuit and means for electrically connecting the said circuits so arranged as to respond normally only to signals from the transmitting circuit of the other of said terminal circuits, and means connected with the receiving circuit of either terminal circuit to indicate the magnitude of the interference set up in that receiving circuit by impulses from the transmitting circuit of the said terminal circuit due to unbalance between the line circuit and the network associated with the same terminal circuit.

11. In an electrical testing system, the combination with a transmitting circuit having a source of current connected therewith, a plurality of networks connected in parallel with the said transmitting circuit, the said networks being also connected serially with a second source of signaling current, a receiving circuit connected with the

said line circuit, means for impressing thereon currents from both of said sources, and means connected with the said receiving circuit to detect the unbalance existing between the said net works arising from the interference between the current from the said source and from the said transmitting circuit.

12. In an electrical testing system, the combination with a transmitting circuit of a receiving circuit, a plurality of networks connected in parallel with the said transmitting circuit, the said net works being also connected serially with a source of signaling current, and means connected with the said receiving circuit to indicate the magnitude of the unbalance existing between the said networks, arising from the interference between the current from the said source and from the said transmitting circuit.

13. In a duplex telegraph signaling system comprising a transmitting circuit, a receiving circuit, a line circuit having a source of signaling current connected therewith, a network intended to balance the said line circuit and a receiving relay having a plurality of windings for electrically connecting the said circuits, the method for determining the magnitude of the unbalance between the line circuit and its network, which consists in simultaneously impressing signaling impulses of a definite frequency from said source upon said line circuit, and also impressing signaling impulses of a different frequency from said transmitting circuit upon said line circuit and said network in parallel, and allowing the resultant current to control the operation of a relay, to impress upon a distortion bridge circuit the impulses from said relay and also from a source having the same frequency as the said first-mentioned source, and to compare the relative strengths of the said impulses by a suitable current indicating device.

14. In a duplex telegraph signaling system, the combination with a line circuit, of a distant transmitting circuit, a home terminal circuit comprising a transmitter adjusted to transmit at a different frequency from the said distant transmitting circuit, a balancing circuit, a receiving circuit, means for electrically connecting the said circuits, and a measuring device associated with the said receiving circuit to measure the magnitude of distortion produced upon signals received from the said line circuit by signals from the said home transmitter due to unbalance between the line circuit and the balancing circuit.

15. In a duplex telegraph signaling system, the combination with a line circuit, of a distant transmitter, a home terminal circuit comprising a transmitter adjusted to transmit signals of a different frequency

from the said distant transmitter, a receiving circuit, a balancing circuit for the said line circuit, a receiving relay having a plurality of windings for electrically connecting the said circuits, and means connected
5 with the said receiving relay for measuring distortion of the received signals by the

transmitted signals, due to unbalance between the said line circuit and its balancing circuit.

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In testimony whereof, I have signed my name to this specification this 15th day of July, 1921.

HARRY NYQUIST.