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A. B. CLARK

METHOD OF AND MEANS FOR MEASURING UNBALANCE

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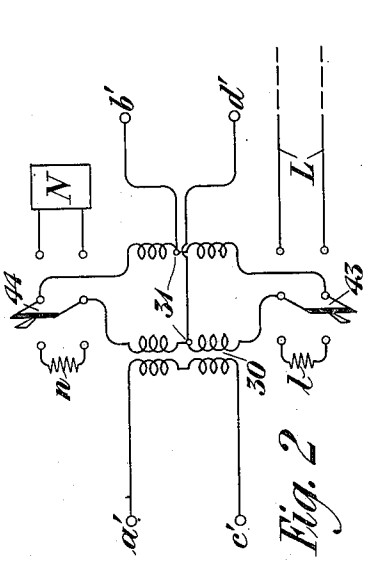

Fig. 2

Fig. 1

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METHOD OF AND MEANS FOR MEASURING UNBALANCE.

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To all whom it may concern:

Be it known that I, ALVA B. CLARK, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Methods of and Means for Measuring Unbalance, of which the following is a specification.

This invention relates to methods of and means for measuring the unbalance between a pair of electrical devices, such as a telephone line and its network.

The closeness of the balance between a line and its network is of high importance in the telephone and telegraph art, because certain apparatus is limited in effectiveness by the extent of the unbalance between the line and network associated therewith. The maximum permissible amplification or gain of a repeater, for example, is limited by the amount of unbalance between the line and network.

The amount of the unbalance must consequently be measured often. Heretofore this was usually done by making impedance measurements separately on the line and the network, and plotting the results as curves for purposes of comparison. This method was exceedingly tedious, and it is the object of this invention to provide a method and means whereby the unbalance at any frequency may be determined by a single measurement.

In this invention the line and network are connected in series with each other in the secondary circuit of a transformer, in whose primary circuit there is a source of current of variable frequency. If the line and network are in perfect balance, i. e., if their impedances are exactly alike, the drop of voltage in the line is the same as the drop in the network, so that the midpoints of the secondary circuit are of the same potential and no current flows through a circuit connected to the said midpoints. When there is an unbalance, however, current enters the said circuit, the strength of this current depending upon the extent of the unbalance.

The combination of the transformer with the line and network thus constitutes a circuit arrangement which transmits a certain value of current to the circuit associated with the said midpoints, according to the extent of the unbalance between the line and the network. The transmission efficiency of this combination thus serves as a measure of the unbalance. In telephone practice it is customary and convenient to express the transmission efficiency of any apparatus in terms of the number of miles of standard cable having like efficiency. The measuring apparatus of this invention is therefore so arranged that the transmission efficiency of the combination above referred to may be ascertained in terms of the number of miles of cable to which the combination is equivalent or, simply, the transmission equivalent thereof in miles. The higher the value of this equivalent, the smaller the unbalance.

One of the inherent advantages of the present method of determining the unbalance is that the result as determined by this measurement gives a direct indication of maximum amplification which may be given to a repeater when the same is associated with the line and network under test, it having been found in practice for certain types of two-way repeaters that the above determined transmission equivalent, reduced by approximately seven miles, is equal to the maximum amplification of the repeater in miles. The measuring apparatus of this invention may be so arranged that the said value of seven miles is automatically deducted from the true transmission equivalent.

A good understanding of the invention may be had from the following description thereof considered in connection with the accompanying drawing showing in Figure 1 a diagrammatic view of one form and arrangement of apparatus embodying the invention, and in Fig. 2, a modification of a portion of said apparatus.

In Fig. 1 reference characters L and N designate the line and network respectively, the unbalance between which is to be determined. A three-winding transformer 30 is provided for associating the line and network in balancing relationship during the test, the arrangement of the windings of the transformer being such that current flowing in the primary winding causes a flow of current through the line and network in

series, so that the midpoints 31 of the secondary windings are at the same potential provided the network and line have the same impedance, that is, are in perfect balance.

The difference between the potentials of the midpoints is thus a measure of the unbalance between the impedance of the line and the impedance of the network, at the frequency under test. The transformer thus transmits from the source associated with the primary to a circuit connected to the midpoints of the secondary, a value of current determined by the extent of the unbalance between the line and the network. The transmission efficiency of this arrangement constitutes, therefore, a measure of the unbalance, as hereinbefore explained. The apparatus described below is so arranged that this efficiency may be ascertained in the number of miles of standard cable equivalent thereto, it being understood, however, that the apparatus may readily be so modified that the unbalance may be ascertained in other units.

The transmission measuring apparatus comprises a source of alternating current variable in frequency, preferably an oscillator, associated with the primary of a transformer 5, the secondary circuit of which comprises resistances 6 and 7 in series with each other. A switch 8 is provided for associating the terminals of the resistance 7 and a measuring circuit M with the primary side of the transformer 30 and the midpoints 31. In the case shown in Figure 1 the resistance 7 is associated with the primary of the transformer 30 and the measuring circuit M with the midpoints 31 of the secondary. Current proportional to the intensity of the source is thus impressed on transformer 30 and current, of a value determined by the transmission equivalent of the combination of the transformer with the line and the network, flows into the measuring circuit M. This circuit comprises an adjustable impedance device 9, preferably an artificial line, the transmission equivalent of which may be varied by means of dials 10 and 11. The current which passes through the device 9 is impressed by a potentiometer 12 on an amplifying element 17, the output current of this element being rectified by an electron tube 13 and caused to flow through a resistance 15. The drop in potential in this resistance depends upon the strength of the source 32, and to render the indicating device in the present arrangement unaffected thereby, I provide a like resistance 15′ which is traversed by current from a rectifier 13′ associated by a reference circuit R with the resistance 6. Resistances 15 and 15′ are connected to each other at one end and associated by a galvanometer 14 at the other end, this galvanometer serving to indicate when the current in one resistance is equal to the current in the other. Condensers 18 and 18′ are connected in parallel with the resistances to improve the action of the galvanometer. A resistance 50 and condenser 51 are included in the reference circuit to make the transmission characteristics of the circuit equal to that of the measuring circuit at all essential frequencies, it being understood, however, that any other suitable device may be used for this purpose.

The transformer 30 may at times be disconnected from the apparatus by reversing switch 8, connections 40 being provided between the lower terminals of the switch to connect the measuring circuit directly to resistance 7 so that the full value of the current is impressed on circuit M for purposes of calibration, as I shall now explain.

To calibrate the measuring circuit, switch 8 is thrown to its lower position so that the circuit M is in direct connection with the resistance 7. The source of current is then regulated to give the desired frequency and the dials 10 and 11 are turned to the position at which the artificial line 9 causes a maximum loss of transmission in circuit M. Potentiometer 12 is then adjusted until the current flowing through the resistances 15 and 15′ are equal, as indicated by the pointer of the galvanometer standing at zero.

To make a measurement of the unbalance between the line and the network, switch 8 is thrown to close its upper contacts, so that the current from the source is impressed on the transformer 30 and only such current enters circuit M as is caused by the difference in potential between points 31 owing to the unbalance between the line and the network. The current which now flows through resistance 15 is less than the current which flowed therethrough during the calibration of the apparatus, so that the galvanometer needle is thrown off its zero position. The transmission equivalent of line 9 is then reduced by rotating the dials 10 and 11 until the current in the measuring circuit is restored to its prior value, as indicated by the return of the galvanometer needle to its middle position. The dials 10 and 11 are calibrated to indicate the number of miles by which the equivalent of the artificial line has been reduced, this quantity being equal to the transmission equivalent of the transformer with the line and the network.

This equivalent, as explained hereinbefore, is a measure of the unbalance between the line and network under test, the greater the value of the equivalent the smaller being the extent of the unbalance. The value of the equivalent moreover, has an important practical significance, for when reduced by seven miles, it represents the maximum al-

lowable amplification or gain (in miles) of a repeater associated with the line and network.

In a modification of the apparatus, the said quantity of seven miles is automatically deducted from the transmission equivalent. This modification is illustrated in Fig. 2, the arrangement therein shown connected to terminals a', b', c', d', being intended to be substituted in Fig. 1 for the circuit connected between terminals a, b, c, and d. The three winding transformer 30 of Fig. 2 is then directly connected to the resistance 7 and the midpoints of this transformer are in direct connection with the artificial line 9. Switches 43 and 44 associated with the secondary terminals of the transformer are provided for at times connecting line L and network N with the transformer and at other times impedance devices n and l which are here shown as simple resistances. These devices are of unequal magnitude and so proportioned that they introduce a loss of transmission between terminals a', c', and b', d', equal to about seven miles, when switches 43 and 44 are thrown to the left. The calibration of the circuit is made with resistance n and l connected to transformer 30 so that when the unbalance measurement is subsequently made on line L and network N, the dials indicate directly seven miles less than the actual equivalent thereof.

The apparatus of this invention is practically independent of current strength because of the use of the reference circuit for balancing the effect of current in the measuring circuit and it is also substantially independent of the frequency of the current, the amplifier being designed to be as distortionless as possible throughout the entire range of frequencies. Thus a single calibration at a frequency of, say, 800 cycles, is sufficient even though measurements are made throughout a wide range of frequencies, and the strength of the source need not be held constant throughout the test. The manner in which the value of the current in the measuring circuit is compared with the value of the current in the reference circuit, is applicable to many other branches of the electrical art. In this aspect, the invention consists in rendering the "null" method broadly applicable to measurements made with alternating currents, this method heretofore having been capable, generally, of use only in measurements with direct currents or alternating currents of like phase, as for example in the D. C. and A. C. bridges. By rectifying the currents before impressing them on the galvanometer the measurement is rendered independent of the relative phases of the currents, or even of their relative frequencies.

Although only two forms of apparatus embodying the invention are shown and described herein it is readily understood that various changes and modifications may be made therein within the scope of the following claims without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of determining the extent of the unbalance at any frequency between a pair of electrical devices, which consists in associating said devices in series relation with a source of current having said frequency and indicating the difference between the potential drops in the said devices.

2. The method of ascertaining the extent of unbalance at any frequency between a pair of electrical devices, which consists in connecting said devices in a circuit in series relation with a source of current of said frequency and obtaining an indication of the value of current in a branch circuit associated with the said circuit at points midway between said devices, as compared with the value of current in said branch circuit when said source is connected directly therewith.

3. The method of determining the extent of the unbalance between a pair of electrical devices, which consists in determining the reduction in the transmission equivalent of a circuit by interposing said devices in balanced relation in said circuit.

4. The method of measuring unbalance between a line and its balancing network, which consists in interposing the points of balance between them in a measuring circuit and applying current from a source through a transformer to the line and the network in series, and cutting out calibrated standard miles in said measuring circuit until the current therein is restored to the value it had as compared with when the source was applied directly to the measuring circuit.

5. The method of determining the extent of unbalance existing between a pair of electrical devices, which consists in connecting said devices in series with the secondary circuit of a transformer, applying a source of current to the primary of said transformer, and ascertaining an indication of the value of current caused thereby in a circuit associated with points midway between said devices, as compared with the current in said circuit when said source is applied directly without the interposition of said transformer and said devices.

6. The method of ascertaining the extent of unbalance existing between a line and a network, which consists in connecting said line and network in series with the secondary winding of a transformer, and ascertaining the transmission equivalent from a source through the primary of said transformer to the midpoints of the secondary

circuit, as compared with the transmission equivalent when said line and network and transformer are omitted and connection is made directly from said source to the conductors formerly connected with said mid-points.

7. The method of determining the extent of the unbalance at any frequency between a pair of electrical devices, which consists in causing a flow of current of said frequency through said devices, causing a current determined by the unbalance which exists between them to flow through a measuring circuit, causing a current determined by the intensity of the current in the said devices to flow through a reference circuit, and adjusting the relative transmission of said measuring and reference circuits until the currents therein have predetermined relative values.

8. The method of determining the extent of the unbalance between a pair of electrical devices, which consists in causing a flow of current through said devices, causing a flow of current determined by the unbalance which exists between them to flow through a measuring circuit and adjusting the transmission of said circuit until the current transmitted thereby has a predetermined value relative to the intensity of the current caused to flow through said devices.

9. The method of determining the extent of the unbalance between a pair of electrical devices which consists in causing a flow of current through said devices, causing a current determined by the unbalance which exists between them to flow through a measuring circuit, adjusting the transmission of said measuring circuit to a predetermined value, and ascertaining the extent of the change in the transmission of said circuit.

10. The method of determining the unbalance between a pair of electrical devices, which consists in applying a source of current to a measuring circuit, then applying said source to said devices and causing a flow of current in the measuring circuit determined by the difference between the impedances of said devices and determining the relative intensities of said currents in said circuits.

11. The method of determining the extent of the unbalance at any frequency between a pair of electrical devices which consists in applying a source of current of said frequency to a measuring circuit and adjusting the transmission of said circuit to a pre-assigned value, then applying said source to a circuit comprised of said devices associated with each other in balancing relationship and causing current determined by the extent of the unbalance between said devices to enter said measuring circuit, adjusting the transmission equivalent of said circuit relatively to said pre-assigned value, and ascertaining the extent of the change in the value of said transmission equivalent.

12. The method of determining the transmission equivalent of an electrical device which consists in causing a flow of current through a measuring circuit to actuate an indicating device in one direction, causing flow of current through a reference circuit to actuate said device in the opposite direction, adjusting the relative value of currents actuating said indicating device to a predetermined value, connecting said first mentioned device in tandem with said measuring circuit, adjusting the transmission equivalent of said circuit until the indicating device is restored to its previous position and ascertaining the extent of the change in the transmission equivalent of said circuit.

13. The method of determining the maximum permissible gain of the amplifying element of a repeater to be associated with a certain line and network, which consists in associating a source of current with a measuring circuit, interposing between said circuit and said source a device for causing a predetermined loss in transmission, adjusting the value of current transmitted by said measuring circuit to a predetermined value relative to the current flowing from said source, removing said device and substituting therefor said line and network associated in balancing relationship so that a current determined by the extent of the unbalance between said line and network enters said measuring circuit, adjusting the transmission equivalent of said measuring circuit until the current leaving said measuring circuit is restored to its previous value and ascertaining the extent of the change in transmission of said circuit.

14. The method of determining the transmission of an electrical device, which consists in impressing current from a source of variable frequency on a current responsive device to actuate the same in one direction, simultaneously impressing current from the same source on a circuit of variable transmission and causing the current transmitted thereby to actuate said responsive device in the other direction, varying the current applied to said translating device to balance the forces actuating the same in opposite directions, connecting the unknown line in tandem with said known circuit, changing the transmission equivalent of the latter to restore balance of the translating device, and ascertaining the extent of the change in the equivalent of said device.

15. In an apparatus for determining the unbalance between a pair of electrical devices, means for associating said devices in balancing relationship, means for applying current of variable frequency thereto, a circuit for receiving the current due to unbal-

ance between the said devices, and means for determining the amount of said current relative to the current applied to said line and network.

16. In an apparatus for determining the amount of unbalance existing between a pair of electrical devices, a source of current, a measuring circuit, means governed by said devices in accordance with the amount of unbalance existing therebetween for applying current from said source to said measuring circuit, a reference circuit also supplied with current from said source, and means for regulating the relative value of current in said circuits.

17. In an apparatus for determining the amount of unbalance existing between a pair of electrical devices, a source of current, a measuring circuit, means governed by said devices in accordance with the amount of unbalance existing therebetween for applying current from said source to said measuring circuit, a reference circuit also supplied with current from said source, an indicating device governed by said circuits and responsive to the values of current therein, and an impedance device associated with one of said circuits for controlling the relative amount of current in said circuits.

18. In an apparatus for determining the amount of unbalance existing between a pair of electrical devices, a source of current, a measuring circuit, means governed by said devices in accordance with the amount of unbalance existing therebetween for applying current from said source to said measuring circuit, a reference circuit also supplied with current from said source, a switch for at times rendering the said devices ineffective to govern the current applied from said source to said measuring circuit, and an impedance device for controlling the relative value of current in said circuits.

19. In an apparatus for determining the amount of unbalance between a pair of electrical devices, a source of current, a measuring circuit, means governed by said devices in accordance with the amount of unbalance existing therebetween for applying current from said source to said measuring circuit, a reference circuit also supplied with current from said source, a switch for at times rendering the said devices ineffective to govern the current applied from said source to said measuring circuit, an impedance device for controlling the relative value of current in said circuits, and an indicating device governed by said circuits and responsive to the relative value of currents therein.

20. In an apparatus for determining the amount of the unbalance between a pair of electrical devices, a source of current, a measuring circuit, means governed by said devices in accordance with the amount of unbalance existing therebetween for applying current from said source to said measuring circuit, a reference circuit also supplied with current from said source, a switch for at times rendering the said devices ineffective to govern the current applied from said source to said measuring circuit, an impedance device for governing the relative values of current in said circuits when said switch is in one position, a second impedance device for governing the relative values of current in said circuits when said switch is in its other position, and an indicating device governed by said circuits and responsive to the relative values of current therein.

21. In an apparatus for determining the amount of the unbalance between a pair of electrical devices, a source of current, a measuring circuit, a reference circuit supplied with current from said source, an indicating device associated with said circuits and actuated in opposite directions by the currents therein, a device for governing the amount of current in said measuring circuit, a switch for at times rendering said device effective to control the amount of current in said measuring circuit in accordance with the amount of unbalance existing between the said pair of electrical devices, an impedance device in said measuring circuit for governing the current in said circuit to have equal values in each position of the switch and means governed by said impedance device for indicating the amount of unbalance between said devices.

22. In an apparatus for determining the transmission of an electrical device, the combination of a source of current, a measuring circuit associated with said source, a reference circuit associated with said source, an indicating device responsive to the relative value of currents in said circuits, means for at times interposing the said electrical device between said source and said measuring circuit, and means for adjusting the value of current in said measuring circuit relative to the current in said reference circuit.

23. In an apparatus for determining the transmission of an electrical device, the combination of a source of current, a measuring circuit associated with said source, a reference circuit also associated with the source, an indicating device actuated in opposite directions by the current in said circuits, means for adjusting the indication of said device to a pre-assigned value, means for connecting tne said electrical device into said measuring circuit, means for adjusting the transmission of said circuit until the indication of said device is returned to said pre-assigned value, and means for indicating the change in the transmission of said circuit.

24. The method of determining the value of alternating current in one circuit relative to the current in another circuit, which con-

sists in rectifying said currents and causing said rectified currents to actuate a current responsive device in opposite directions.

25. In combination, a source of alternating current, a first circuit associated therewith, a translating device, a rectifier for causing the current from said first circuit to actuate said device in one direction, a second circuit also associated with said source, and a rectifier for causing the current from said second circuit to actuate said device in the opposite direction.

26. The method of measuring unbalance between a line and its balancing network, which consists in interposing the points of balance between them in a measuring circuit and cutting out calibrated standard miles in said circuit till the current therein is restored to the value it had before the interposition was made.

27. The method of measuring unbalance between two electrical devices which consists in energizing them in a circuit in which they are on opposite sides of two points of equal potential if the balance is perfect, and connecting these two points in another circuit and measuring the transmission equivalent in said other circuit necessary to compensate for the unbalance.

28. In combination, a transformer with two secondary windings, two electrical devices alternately in series with said windings in a circuit, another circuit comprising two points in said secondaries respectively of equal potential when said two devices are in balance, and calibrated means in said other circuit to measure the actual unbalance of said devices.

29. In a circuit for measuring transmission, a path having a calculable transmission efficiency, a path comprising apparatus to be tested, a variable resistance in one of said paths for rendering the transmission through said paths equal, and means for passing alternating current through said paths in series.

30. The method of measuring the transmission of electrical apparatus, which comprises sending an alternating current through a path containing said apparatus and a second path in series, and adjusting one of said paths until the transmission therethrough is equal to the transmission through the other of said paths.

In testimony whereof, I have signed my name to this specification this 10th day of October, 1919.

ALVA B. CLARK.