Aug. 5, 1924.

1,503,650

W. J. HERDMAN

DUPLEX REPEATER

Original Filed July 10, 1920 2 Sheets-Sheet 1

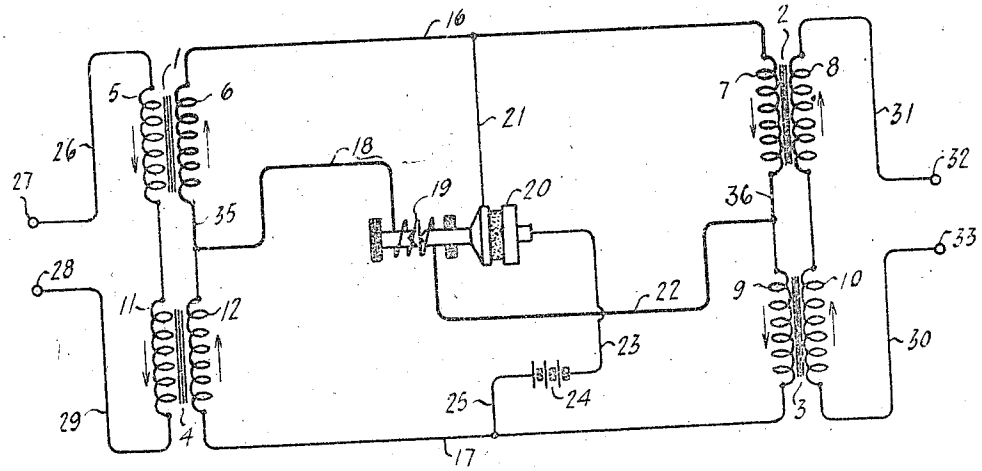

FIG. 1.

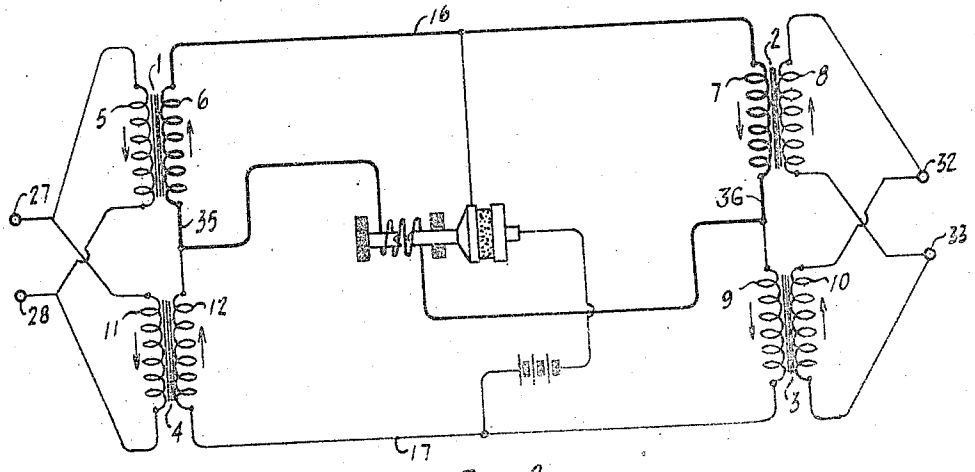

FIG. 2.

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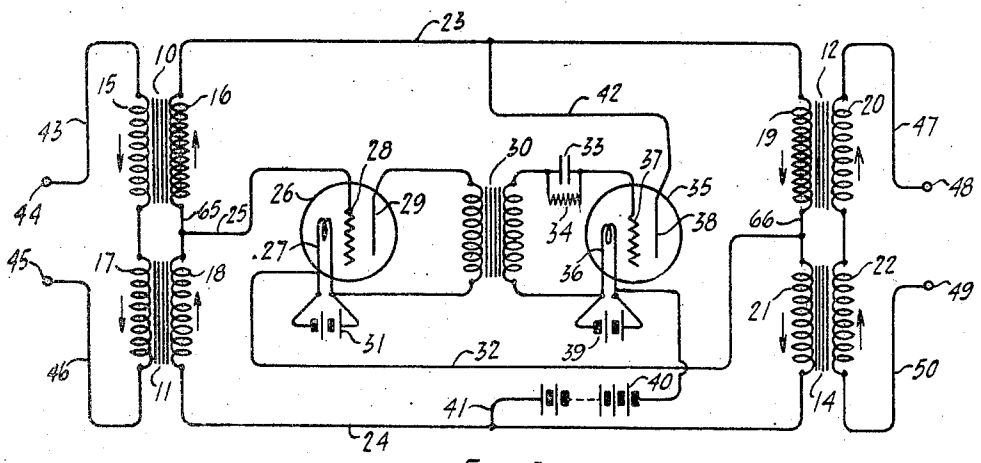

FIG. 3.

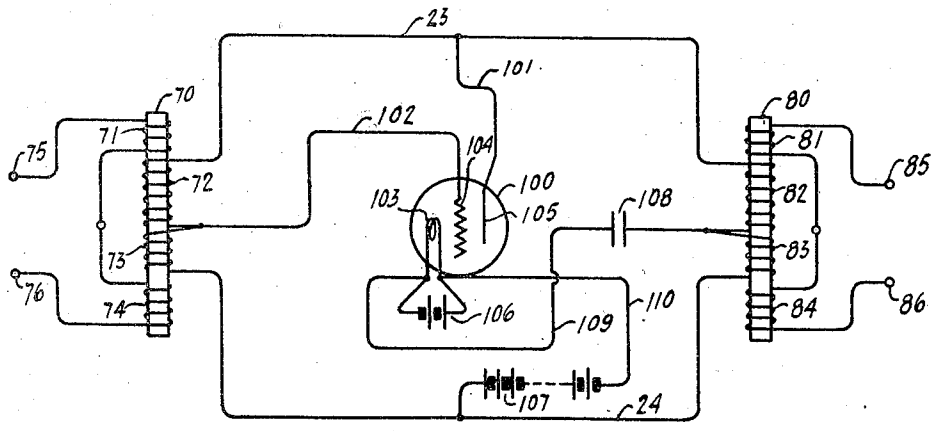

FIG. 4.

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UNITED STATES PATENT OFFICE.

WILLIAM J. HERDMAN, OF TORONTO, ONTARIO, CANADA.

DUPLEX REPEATER.

Application filed July 10, 1920, Serial No. 395,251. Renewed December 26, 1923.

To all whom it may concern:

Be it known that I, WILLIAM J. HERDMAN, a citizen of the United States of America, and a resident of Toronto, county of York, and Province of Ontario, Canada, have invented a new and useful Improvement in Duplex Repeaters, of which the following is a specification.

My invention relates to signal or voice current repeaters and pertains specifically to that class of such devices which augment or amplify the currents received without distorting the same.

The principal objects of my invention comprise, producing a repeater which is duplex in operation, in that it repeats in either of two directions with equal facility, a repeater that is self balancing or compensating with regard to the length of lines or load connected thereto, and one that is extremely simple in construction, operation and maintenance.

I accomplish these and other very desirable features which will hereinafter be pointed out and described, by means of a novel arrangement of apparatus and circuits whereby incoming signals or voice currents from either direction may be detected by suitable receiving apparatus, and the amplified or augmented energy returned to the line conductors in such manner that the receiving device is not sensible thereto; even though the lines connected to the repeater are unbalanced with regard to length or load condition.

In the figures which accompany and form a part of this specification, and in which like reference numerals designate corresponding parts throughout;

Fig. 1 illustrates diagrammatically the apparatus and circuits comprising one embodiment of my invention, utilizing electromagnetic receiving means and microphonic transmitting means.

Fig. 2 illustrates diagrammatically a different method of connecting the line conductors to the circuits and apparatus shown in Fig. 1.

Fig. 3 illustrates diagrammatically the apparatus and circuits comprising a further embodiment of my invention, utilizing vacuum tubes as receiving and transmitting means.

Fig. 4 illustrates in diagram a still further embodiment of my invention and shows a preferred form of transformer for use with the same.

Referring now particularly to the arrangement shown in Fig. 1, my invention comprises the transformers 1, 2, 3 and 4, one winding of each, as 6, 7, 9 and 12 respectively, being connected in series to form the closed circuit; winding 6, conductor 16, winding 7, conductor 36, winding 9, conductor 17, winding 12 and conductor 35. Preferably the windings so connected are those known as the secondary windings. The remaining or primary windings 5 and 11 of transformers 1 and 4 respectively, are connected in series and through conductors 26 and 29 to binding posts 27 and 28 respectively, to which line conductors may be connected, likewise the remaining or primary windings 8 and 10 of transformers 2 and 3 respectively, are connected in series and through conductors 31 and 30 with binding posts 32 and 33 respectively, to which line conductors are also intended to be attached. The closed circuit comprised of the secondary windings of the transformers constitutes a Wheatstone bridge, in which the windings comprise the four arms of the bridge. The windings constituting the arms of the bridge are so related to each other with regard to resistance, reactance and turns that the product of the impedance of winding 7, multiplied by the impedance of winding 12 is exactly equal to the product of the impedance of winding 6 multiplied by the impedance of winding 9 and thus the arrangement is in perfect balance when traversed by either direct or alternating current entering the bridge at the mid points of conductors 16 and 17. An electromagnetic receiving device 19, such as is common in the art, is connected by conductor 18 with the mid point of conductor 35 and through conductor 22 with the mid point of conductor 36. The receiving device 19 is as shown functionally related to a microphonic transmitting device 20, also well known in the art, one terminal of which is connected through conductor 21, with the mid point of conductor 16 and the other terminal of which is connected through conductor 23, battery 24 and conductor 25 with the mid point of conductor 17. In other words, the receiving device 19 is connected to the bridge at points thereof corresponding to the galvanometer

connection in an ordinary bridge that is to say, to a pair of conjugate points, while the transmitting device 20 is connected to points of the bridge corresponding to the battery connection in an ordinary bridge that is to say, to the other pair of conjugate points of the bridge. In practice and preferably, the windings 6, 7, 12 and 9 are made equal with regard to turns. The windings 6 and 7 are equal in resistance but of very much lower resistance than the resistance of the windings 12 and 9, which are likewise equal in resistance and the closed circuit or bridge is therefore very much unbalanced to current traversing it from the mid point of conductor 35 to the mid point of conductor 36. Thus if this arrangement of circuits and apparatus be connected by binding posts 27, 28 and 32, 33 in a telephone line for example the voice currents traversing windings 5 and 11 in the direction indicated by the arrows, will generate corresponding voice currents in the windings 6 and 12 in the direction of the arrows shown near these windings and obviously, more current will flow through the path, winding 6, conductor 16, winding 7, conductor 22, receiving device 19 and conductor 18 than will flow through the path, winding 12, conductor 17, winding 9, conductor 22, receiving device 19 and conductor 18, because the former path is of very much lower resistance. Obviously, the currents flowing through conductor 22, receiving device 19 and conductor 18 will be in opposite directions, but the algebraic sum of these two currents will cause the receiving device 19 to operate the diaphragm of the transmitting device 20 and thus an augmented current of similar wave form will be transmitted to the bridge arrangement through the mid points of conductors 16 and 17. This augmented current will divide at the mid points of conductors 16 and 17 and part of this current will flow through windings 6 and 12 and part of the current will flow through windings 7 and 9, and no flow of current nor any difference of potential will be manifested in receiving device 19, because the drop in potential along each of the two paths just indicated is equal. Thus no interference can result through regenerative action and the augmented current will be inductively transmitted through the transformers 1, 2, 3 and 4 to the telephone lines connected to the device.

It will further be obvious that if the primaries 5 and 11 of the transformers 1 and 2 have the same number of turns and resistance, and if the cores of these transformers are equal in weight and character of iron, that any change in the line connected to binding posts 27 and 28 with regard to either length of line or loading of line will not cause any unbalancing of the local closed circuit or bridge because such change will affect the impedance of both winding 6 and winding 12 equally and the condition necessary for balance of the bridge, viz,

impedance of 6 × impedance of 9 = impedance 7 × impedance of 12;

will be maintained because both sides of the above equation will have been equally modified, through the equal modification of an element in each side of the equation. This is of course equally true of lines connected to binding posts 32 and 33; therefore the arrangement is automatically self balancing or self compensating where long or short lines are connected thereto or where combinations of long or short lines or unequally loaded lines are connected thereto.

Fig. 2 illustrates a different method of connecting the primaries of the transformers to the line conductors, and as indicated shows primaries 5 and 11 connected in parallel to binding posts 27 and 28 and primaries 8 and 10 likewise connected in parallel and to binding posts 32 and 33. This arrangement functions in exactly the same manner as the arrangement just described and shown in Fig. 1.

In Fig. 3 there is shown an embodiment of my invention, employing vacuum tubes or electron discharge devices for the reception and transmission of signals or voice currents. In this arrangement, because the three element vacuum tube or audion is primarily a potential detector, the transformers 10 and 12 are provided with secondaries 16 and 19 respectively, having a great many more turns thereon than their associated primaries 15 and 20. The secondaries 18 and 21 have the same number of turns as their associated primaries 17 and 22 and the primaries 15 and 17 and 20 and 22 are uniform with regard to turns and resistance. It will thus be noted, that as before, the closed circuit; winding 16, conductor 23, winding 19, conductor 66, winding 21, conductor 24, winding 18 and conductor 65 constitutes a Wheatstone bridge in which the arms are the secondaries of the transformers 10, 11, 12 and 14, and in which incoming signals or voice currents generate much higher potentials in the windings 16 and 19 than in the windings 18 and 21. There is thus a very appreciable difference of potential available for impression from the mid point of conductor 65 through conductor 25 to the grid 28 of the detecting audion 26, the filament of which is connected through conductor 32 with the mid point of conductor 66 to complete the detecting circuit of the audion. A battery 31 is provided to illuminate the filament 27 of the audion 26 and the plate 29, is connected as shown to a terminal of

one winding of the inter-valve transformer 30, the other terminal of which is connected to the filament 27. The remaining winding of the inter-valve transformer is connected by one terminal through condenser 33, which is bridged by a grid leak resistance 34, to the grid 37 of the amplifying audion 35, and the other terminal of the winding is connected to the filament 36 of audion 35, the plate 38 of which is connected through conductor 42 to the mid point of conductor 23. The filament 36 is illuminated by battery 39 and is connected to the plate battery 30, the positive terminal of which is connected through conductor 41 to the mid point of conductor 24. Such interconnection of audions is common in the art and it is thought that any description of the action of the audions is unnecessary.

It will be sufficient to say that the amplified and undistorted currents emanating from the output circuit of the audion 35 will as heretofore described divide at the mid points of conductors 23 and 24 and a portion of the current will traverse the secondaries 16 and 18, while the other portion of the current will traverse secondaries 19 and 21 to generate currents in their respectively associated primaries to thus impress the augmented current on the line conductors connected to the device at the binding posts 44, 45 and 48, 49. Further, if, as heretofore explained, the product of the impedance of winding 16 multiplied by the impedance of winding 21 is equal to the product of the impedance of winding 19 multiplied by the impedance of winding 18, there will exist no difference of potential at the mid points of conductors 65 and 66 and the detecting audion 26 will therefore not be sensible to the amplified currents and hence no oscillation or regenerative action of the system of audions can result. Further, as the impedance of each pair of primaries connected to the lines is equal, any change in the impedance of their associated pair of secondaries due to difference of length of line or loading condition of line cannot result in unbalancing the closed circuit or bridge as heretofore explained.

Fig. 4 illustrates a preferred embodiment of my invention in which but two transformers are utilized and in which the primaries 71 and 74 are both wound in the same direction upon the core 70 and are connected in series as shown. These primaries correspond to the primaries 15 and 17 of Fig. 3. The secondaries 72 and 73 are likewise wound in the same direction upon core 70 and correspond to the secondaries 16 and 18 shown in Fig. 3. The secondary 72 contains many more turns than the secondary 73 or than the total turns of the two primaries 71 and 74. In practice, I prefer to make the total turns of the primaries 71 and 74 equal to the turns in the secondary 73, while the secondary 74 has from fifty to one hundred times more turns than the secondary 73 or the two primaries 71 and 74 combined and preferably windings 71 and 74 are wound in one continuous winding of uniform length with the core, while the two secondaries are wound separately, superposed in each other and likewise of uniform length with the core. Similarly, the primaries 81 and 84 are wound on core 80, while the secondaries 82 and 83 are likewise wound on the same core and connected as shown to complete the system. The terminals of primaries 71 and 74 are connected as shown to binding posts 75 and 76, while the terminals of primaries 81 and 84 are likewise connected to binding posts 85 and 86. In this embodiment the audion 100 constitutes the repeating relay, and the grid 104 is connected through conductor 102 with the mid point of the conductor connecting secondaries 72 and 73. The filament 103 is illuminated by battery 106 and is connected through conductor 109 and condenser 108 with the mid point of conductor connecting secondaries 82 and 83. The plate 105 is connected through conductor 101 with the mid point of conductor 23 while the filament is connected through conductor 110 and plate battery 107 with the mid point of conductor 24. From the previous descriptions, it will be obvious that the audion 100 constitutes a repating relay, the input circuit of which is connected to the Wheatstone bridge at the points of zero potential thereof, while the output circuit of the audion is connected to the bridge at the points of energy input thereof and that therefore, the operation of the system is the same as that hitherto described.

From the foregoing, it will be obvious that I have produced a signal or voice current repeater that is capable of duplex operation in that it will transmit with equal facility in either of two directions without interference; that my device is automatically self compensating or balancing with regard to the lengths or load conditions of the lines to which it is attached and that further my device is extremely simple and rugged in construction, operation and maintenance.

It should be noted that while I have described four embodiments of my invention, I wish it to be clearly understood that I may vary the details thereof without departing from the spirit or narrowing the scope of my invention.

Having thus fully described my invention what I claim as new and desire to secure by United States Letters Patents is as follows:

1. In a signal repeater, a line circuit to carry input energy, two local circuits

adapted to receive electrical energy in unequal quantities respectively from said line circuit, a conductor common to said two local circuits and in which conductor the electrical energy in one circuit opposes the electrical energy in the other circuit, a detector in said common conductor and responsive to the surplus of electrical energy in one local circuit over the electrical energy in the other local circuit, an output source controlled by said detector, a local circuit for said output source; and a second line circuit associated with said last mentioned local circuit and adapted to carry output energy.

2. In a duplex repeater, two line circuits to carry input and output energy, two local circuits adapted to receive electrical energy in unequal quantities respectively from either of said line circuits, each of said line circuits giving energy to both of said local circuits, a conductor common to said two local circuits and in which conductor the electrical energy in one circuit opposes the eletrical energy in the other circuit, a detector in said common conductor and responsive to the surplus electrical energy in one local circuit over the electrical energy in the other local circuit, an output source controlled by said detector, a local circuit system for said output source, said local circuit system associated with said two local circuits to deliver energy to them, and said line circuits associated with said local circuit system.

3. In a signal repeater, an incoming line, an outgoing line, two local receiving circuits associated inductively with said incoming line in such manner that the two receiving circuits receive different quantities of energy from said line, two local transmitting circuits associated inductively with said lines, a detector, a source of electrical energy, said receiving circuits acting differentially upon said detector, said source acting to impress equal potentials upon said transmitting circuits, said detector and said source being associated to form a repeating relay for alternating currents, and each of said two transmitting circuits having parts in common with both of said two receiving circuits.

4. In a signal repeater, two local receiving circuits, a detector common to said two circuits, upon which said receiving circuits act in opposing manner so that the said detector responds to the algebraic sum of the energy in said two receiving circuits, two local transmitting circuits, a source of energy common to said two transmitting circuits to which said source delivers equal potential at any instant, said two transmitting circuits conductively connected to said detector circuits by reason of common paths in such manner that said detector is neutral to currents in said two transmitting circuits and therefore unresponsive to them, and said detector and said source being associated to form a repeating relay.

5. In a duplex repeater, a Wheatstone bridge the arms of which are composed of impedances so related that while the bridge is in a state of balance, the arms associated with one pair of the conjugate points thereof are of unequal impedance, signal receiving means associated with a pair of conjugate points of said bridge, signal transmitting means cofunctionally related to said signal receiving means and associated with the other pair of conjugate points of said bridge, and transmission lines inductively associated with the impedances forming the arms of said bridge.

6. A duplex repeater comprising, a plurality of impedances, a Wheatstone bridge the arms of which are composed of said impedances so related that while said bridge is balanced, the arms adjacent each of a pair of conjugate points of the bridge are of unequal impedance, signal receiving means associated with a pair of conjugate points of said bridge, signal transmitting means cofunctionally related to said signal receiving means and likewise associated with the remaining pair of conjugate points of said bridge, and transmission lines associated with the impedances forming the arms of said bridge.

7. In a duplex repeater, a plurality of transformers, similar windings of said transformers being interconnected to form a Wheatstone bridge, the impedance of said windings being so related that while the bridge is in a state of balance, the windings associated with one pair of the conjugate points thereof are of unequal impedance, a repeating relay, the input circuit of said relay being associated with one pair of the conjugate points of said bridge, the output circuit of said relay being associated with the other pair of conjugate points of said bridge, and transmission line conductors connected to the remaining windings of said transformers.

8. In a duplex repeater, a plurality of transformers, corresponding windings of each of said transformers being connected to form a balanced Wheatstone bridge, the windings associated with one pair of the conjugate points thereof being unequal in impedance, a repeating relay the input circuit of which is connected to one pair of the conjugate points of said bridge and the output circuit of which is connected to said bridge at the other pair of conjugate points thereof, and transmission lines connected to the remaining windings of said transformers.

9. In a duplex repeater, a plurality of impedances, said impedances being inter-

connected to form a balanced Wheatstone bridge, the impedances adjacent each of a pair of conjugate points of said bridge being unequal in impedance, a repeating relay, the input circuit of said relay being associated with one pair of conjugate points of said bridge, the output circuit of said relay being associated with the other pair of conjugate points of said bridge, and transmission lines inductively related to the impedances forming said bridge.

WILLIAM J. HERDMAN.

Witnesses:
E. LAIDLAW,
M. ABELL.