G. CRISSON.

REPEATER CIRCUIT.

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1,353,637

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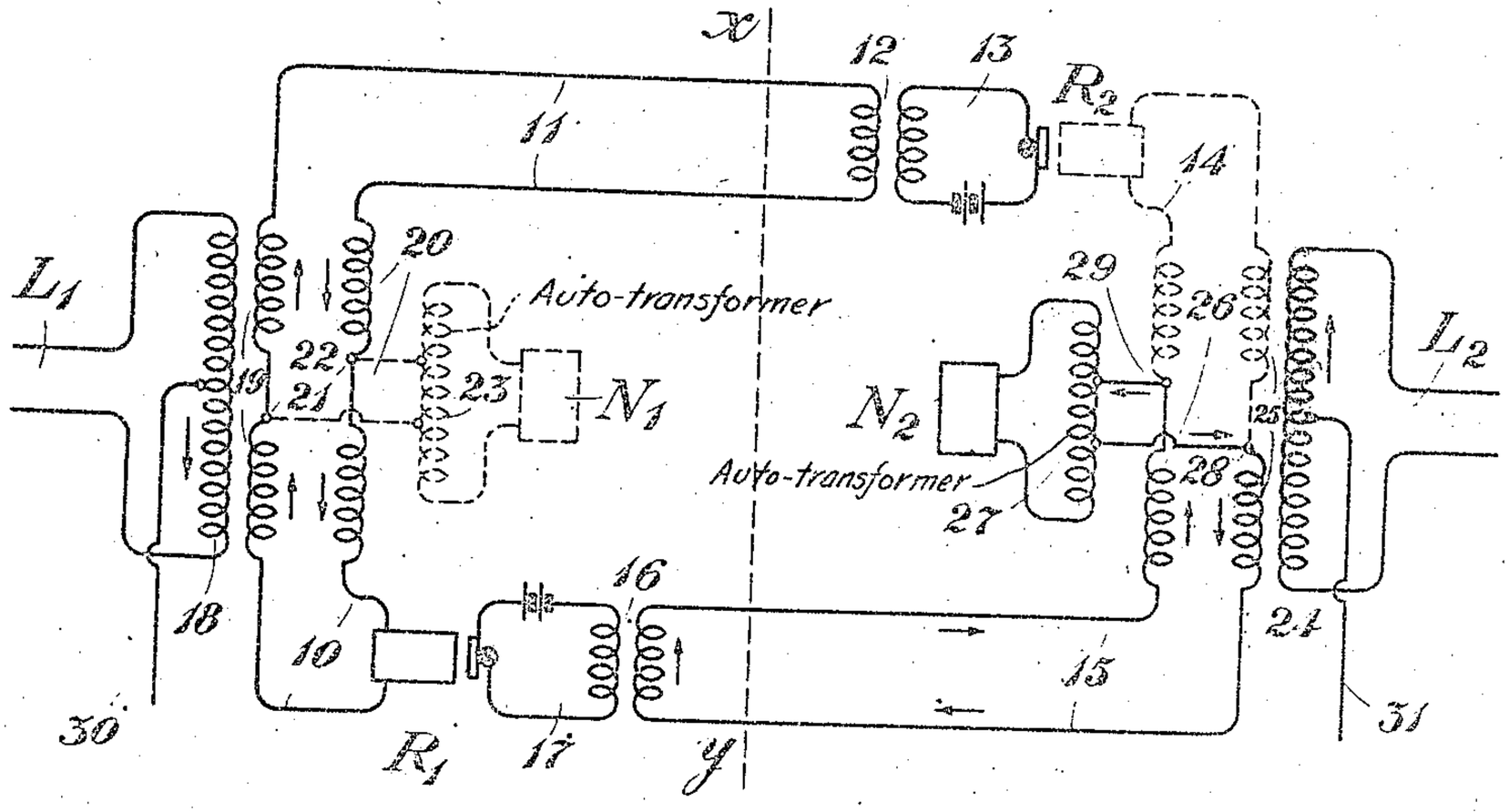

Fig. 1

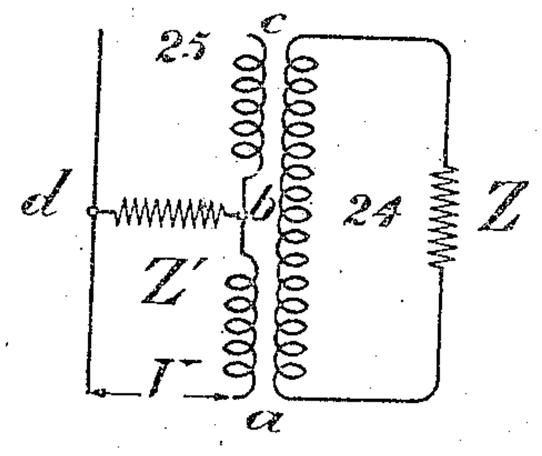

Fig. 2

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REPEATER-CIRCUIT.

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To all whom it may concern:

Be it known that I, GEORGE CRISSON, residing at Hoboken, in the county of Hudson and State of New Jersey, have invented certain Improvements in Repeater-Circuits, of which the following is a specification.

This invention relates to repeater circuits and more particularly to means for associating a repeater circuit of either the two-way two-repeater type or of the well-known four-wire type with terminal two-wire transmission lines.

One of the objects of the invention is the provision of a means for associating a repeater circuit with the terminal two-wire line in such a manner that the two-wire line shall be insulated from the repeater circuit.

Another object of the invention is to provide a connecting arrangement for a repeater circuit and a terminal line of such character that the terminal line may be phantomed or simplexed without the use of an additional repeating coil.

Other and further objects of the invention will appear from the following description when read in connection with the accompanying drawing, Figure 1 of which constitutes a circuit diagram of the preferred embodiment of the invention and Fig. 2 of which is a schematic diagram illustrating certain features of the operation.

Referring to Fig. 1, a repeater circuit including repeaters R_1 and R_2 is shown interconnecting terminal two-wire lines L_1 and L_2. The repeaters R_1 and R_2 are illustrated as being of mechanical type but it will be understood that repeaters of any other type, such as the well known vacuum tube repeater, may be employed. The input circuit 10 of repeater R_1 is connected to the circuit 11 which is associated through the transformer 12 with the output circuit 13 of repeater R_2. In a similar manner the input circuit 14 of repeater R_2 is connected with the circuit 15 which is associated through the transformer 16 with the output circuit 17 of repeater R_1. In order to associate the repeater circuit with the line L_1 a transformer is provided having a winding 18 which terminates the line circuit and divided windings 19 and 20 arranged with one-half of each winding in circuits 10 and 11 respectively. Where circuits 10 and 11 are not exposed to external disturbances one of the windings may be omitted.

In order to balance the line L_1 an artificial line or network, N_1 is provided, said artificial line being bridged across the junction points 21 and 22 of the circuits 10 and 11. The impedance of this artificial line N_1 must have the same phase angle as the impedance of the line L_1 but may differ from it in magnitude. The ratio of the impedance of the artificial line N_1 to that of the line L_1 depends upon the relative number of turns in the windings 18 and 19 and 20. This relation is given by the equation

$$r = \frac{1}{4n^2}$$

in which r is ratio of the impedance of the artificial line N_1 to the impedance of the line L_1 and n is the ratio of the number of turns in winding 18 to the number of turns in windings 19 and 20 together. This requirement may be met by designing the artificial line N_1 to have the correct impedance, for connection directly to the points 21, 22 but it is usually more convenient to give to the artificial line N_1 the same impedance as the line L_1 and obtain the correct ratio by means of an auto-transformer 23 inserted between it and the points 21, 22. In the frequently occurring case in which the transformer is designed for equal impedances in the circuits L_1, 10, and 11 the ratio of the auto-transformer would be two to one.

In a similar manner the line L_2 is associated with the repeater circuit by means of a transformer, including a winding 24 in the line circuit and split windings 25 and 26 in circuits 14 and 15 respectively. An artificial line N_2, which may have in circuit therewith auto-transformer 27, is bridged between points 28 and 29 in order to balance the line L_2.

It will be seen that the above arrangement is such that the output and input circuits of the two repeaters are conductively connected while the repeater circuit as a whole is associated with the terminal lines inductively only. The terminal circuits are therefore insulated from the repeater circuit and may be phantomed or simplexed by connecting leads 30 and 31 to the midpoints of windings 18 and 24, without necessitating the provision of separate phantom or simplex coils.

The arrangement above described may be used either for a two-way two-repeater cir-

cuit or for a four-wire repeater circuit. The circuit as shown is that of a two-way two-repeater circuit but if the apparatus on each side of the vertical dotted line x y be separated and arranged at distant stations, the circuits 11 and 15 being correspondingly lengthened into a pair of two-wire transmission lines, the arrangement becomes that of a four-wire system.

In order to more clearly indicate the operation in transmitting from line L_1 to L_2, those portions of the circuit in which substantially no current flows are indicated by dotted lines. The operation is as follows:

An alternating telephone current flowing in the line L_1 will at a given instant flow in the direction indicated by the arrow to the left of winding 18. The current thus flowing induces potentials in the two halves of windings 19 and 20 of such character that currents tend to flow in the directions indicated by the arrows adjacent to halves of said windings. Assuming that the potentials induced in the two halves of each winding are equal and that the impedances in circuits 10 and 11 are approximately equal, points 21 and 22 will be at substantially the same potential so that substantially no current flows through the circuit including the network N_1 and the auto-transformer 23.

On the other hand a current flows in series in the input circuit 10 of repeater R_1 and the output circuit 11 of repeater R_2. The energy dissipated in the latter circuit is without effect but the current flowing in the circuit 10 actuates repeater R_1 and transmits through the transformer 16 a current having at a given instant the direction indicated by the arrows in circuit 15. The action of the transformer, including windings 24, 25 and 26, is such that this current in flowing through the lower halves of windings 25 and 26 induces an electromotive force in the upper halves of said windings, said electromotive force being substantially equal and opposed to the potential difference set up between points 28 and 29 by the current flowing through the impedance of the artificial line N_2 and the auto-transformer 27, so that substantially no current flows in the input circuit 14 of the repeater R_2 but substantially the entire current flowing from circuit 15 takes a path through the bridged circuit including the auto-transformer 27 and balancing network N_2. An electromotive force is induced in the winding 24 whereby a corresponding current flows to the line L_2.

In order to more clearly understand the action of the transformer just described, attention is called to Fig. 2 in which the transformer arrangement is simplified. Let us assume that the impedance of the line L_2 be represented by Z included in series with the winding 24 and that the winding 26 be incorporated in the winding 25. This latter assumption is justified by reason of the fact that the winding 26 is only provided in order to balance the two halves of circuits 14 and 15 respectively. Let the impedance bridged across the junction points of circuits 14 and 15 be represented in the diagram of Fig. 2 by an impedance Z' bridged across points b and d. The winding of the transformer is such that assuming the action of the transformer to be that of a perfect transformer, the impedance of the circuit including impedance Z as seen from the points a and b of the lower half of the winding 25 is equal to impedance Z'. If now the circuit connecting points c and d be opened and a voltage V be impressed between points a and d, the voltage drop between a and b will be equal to the voltage induced between b and c since both parts of the winding 25 are on the same core and have the same number of turns. Furthermore, since due to the impedance relations above referred to, the drop between points a and b is equal to that between points b and d, it follows that the potential difference between points b and c also equals that between points b and d. Points c and d are therefore at the same potential when a voltage is applied between points a and d and consequently no current will flow through a connection between points d and c whatever may be the impedance included in such connection. It follows, therefore, that in Fig. 1 a voltage impressed in the circuit 15 will cause no current flow in the circuit 14 regardless of what may be the impedance of the latter circuit.

The action above described would in practice only be approximated because the primary current entering the transformer from circuit 15 contains a component, known as the exciting current, which magnetizes the core and which is not reproduced in winding 24. This exciting current, flowing through the impedance of the artificial line N_2 and the auto-transformer 27 causes the potential difference between points 28 and 29 to differ slightly from the electromotive force induced in the upper halves of windings 25 and 26. Consequently there would be a certain amount of transmission from circuit 15 to circuit 14. It is possible, however, to compensate for this effect by designing the auto-transformer 27 so that its exciting current is equal to that of the transformer, or by bridging an additional impedance member across terminals 28 ad 29 so as to provide a suitable path for the exciting current between these points. This would involve making the open circuit impedance of the auto-transformer, (or the auto-transformer and impedance member in parallel) equal to one-fourth of the impedance of the transformer measured from the circuit 14 with

circuit 15 short circuited and the circuit of the line L_2 and the bridged circuit including the auto-transformer 27 and artificial line N_2 left open.

The action in transmitting from line L_2 to line L_1 is similar to that above described. In this case substantially no current will flow in the circuit bridged between points 28 and 29 and substantially no current flow will occur in the circuit 10.

This repeater circuit would also function in substantially the same manner if each line such as L_1 were interchanged with the corresponding artificial line N_1. In this case the current entering the circuit at points 21, 22 from the line L_1 would divide into two substantially equal parts which would flow in opposite directions in the two halves of the windings 19, 20 and consequently would have substantially no effect upon winding 18 and the artificial line N_1. In other respects the action would be unchanged.

While the invention has been disclosed in what is believed to be its most desirable form, it will be obvious that the general principles thereof may be embodied in many other organizations widely different from that illustrated without departing from the spirit of the invention as described in the following claims.

What is claimed is:

1. In a telephone system, a pair of transmission lines, a repeater circuit interconnecting said lines, said repeater circuit including one-way paths for transmitting in opposite directions, and means for associating the ends of said paths with said transmission lines, said means comprising transformers having one winding in the transmission lines and divided windings arranged with one-half in each path, and balancing networks bridged across the junction points of the paths at the midpoints of the divided windings.

2. In a telephone system, a transmission line, a repeater circuit associated with said line, said repeater circuit including one-way paths for transmitting in opposite directions, and means for associating the ends of said paths, with said line, said means comprising a transformer having one winding in the line and a divided winding arranged with one-half in each path, and a balancing network bridged across the junction points of the paths at the midpoint of the divided winding.

3. In a telephone system, a pair of transmission lines, a repeater circuit interconnecting said lines, said repeater circuit including one-way paths for transmitting in opposite directions, and means for associating the ends of said paths with said transmission lines, said means comprising transformers having one winding in the transmission lines and divided windings arranged with one-half in each path, and balancing networks bridged across the junction points of the paths at the midpoints of the divided windings, said bridged circuits including transformers whereby the impedance of the balancing networks as viewed from the bridging points will have the correct ratio to that of the lines.

4. In a telephone system, a transmission line, a repeater circuit associated with said line, said repeater circuit including one-way paths for transmitting in opposite directions, and means for associating the ends of said paths with said line, said means comprising a transformer having one winding in the line and a divided winding arranged with one-half in each path, and a balancing network having an impedance equal to the line impedance and included in a circuit bridged across the junction point of said paths at the midpoint of said divided winding, said bridged circuit including a transformer whereby the impedance of the balancing network as viewed from the bridging points will have the correct ratio to that of the line.

5. In a telephone system, a pair of transmission lines, a repeater circuit interconnecting said lines, said repeater circuit including one-way paths for transmitting in opposite direction, and means for associating the ends of said paths with said transmission lines, said means comprising transformers having one winding in the transmissison lines and divided windings arranged with one-half in each path, balancing networks bridged across the junction points of the paths at the midpoints of the divided windings, and means associated with said networks to compensate for the effect of the exciting current of the transformer.

6. In a telephone system, a transmission line, a repeater circuit associated with said line, said repeater circuit including one-way paths for transmitting in opposite directions, and means for associating the ends of said paths with said line, said means comprising a transformer having one winding in the line and a divided winding arranged with one-half in each path, a balancing network bridged across the junction points of the paths at the midpoints of the divided winding, and means associated with said network to compensate for the effect of the exciting current of the transformer.

7. In a telephone system, a transmission line, a two-way repeater circuit, means to associate said repeater with said line comprising a transformer having one winding in the transmission line and a divided winding having one-half in the output circuit of

one repeater element and the other half in the input circuit of another repeater element, and a balancing network, said input and output circuits being joined together with said balancing network bridged across the junction points thereof at the midpoints of the divided winding.

8. In a telephone system, a repeater apparatus including one-way paths for transmitting in opposite directions, a transmission circuit and a balancing circuit, and means to associate said circuits with the ends of said paths, said means comprising a transformer having a divided winding arranged with one-half in each path and another winding arranged in one of said circuits, the other circuit being bridged across the junction points of the paths at the midpoints of the divided winding.

9. In a telephone system, a pair of transmission circuits and a repeater apparatus including two elements, means to associate said repeater apparatus with said circuits comprising a transformer having a divided winding arranged with one-half associated with each of the two elements of the repeater apparatus and a second winding arranged in one of said transmission circuits, the other transmission circuit being bridged across the junction points of the repeater elements at the midpoints of the divided winding.

10. In a telephone system, a pair of terminal transmission lines terminating at geographically distant stations, a four wire repeater circuit interconnecting the two stations, said repeater circuit including a pair of one-way transmission lines for transmitting in opposite directions, means for associating the ends of said one-way lines with said terminal lines, said means comprising transformers having one winding in the terminal transmission lines and divided windings arranged with one-half in each one-way line and balancing networks bridged across the junction points of the paths at the midpoints of the divided windings.

In testimony whereof, I have signed my name to this specification this twenty-first day of December 1918.

GEORGE CRISSON.