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REPEATER SYSTEM

Filed June 7, 1928.

2 Sheets-Sheet 1

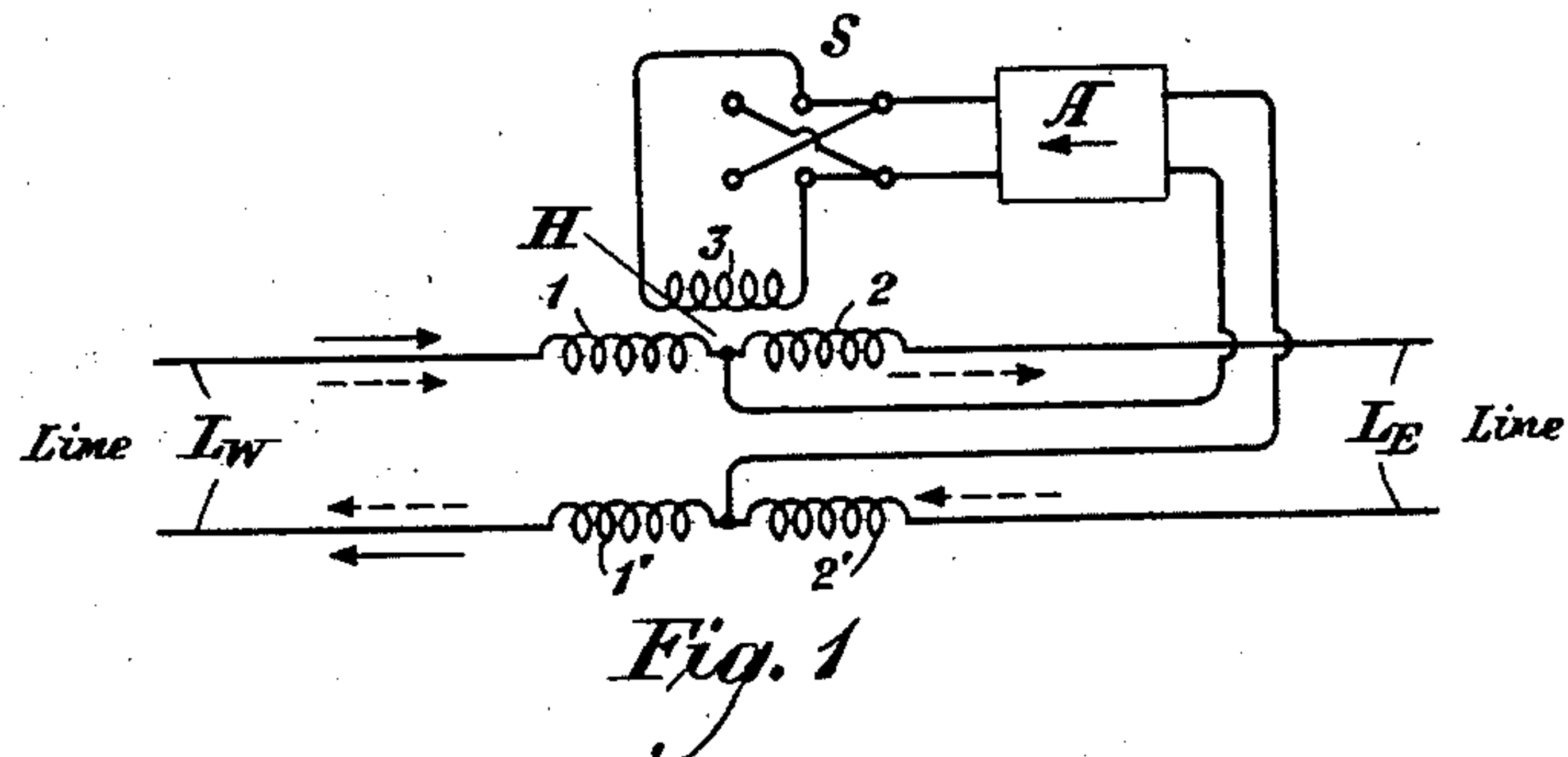


Fig. 1

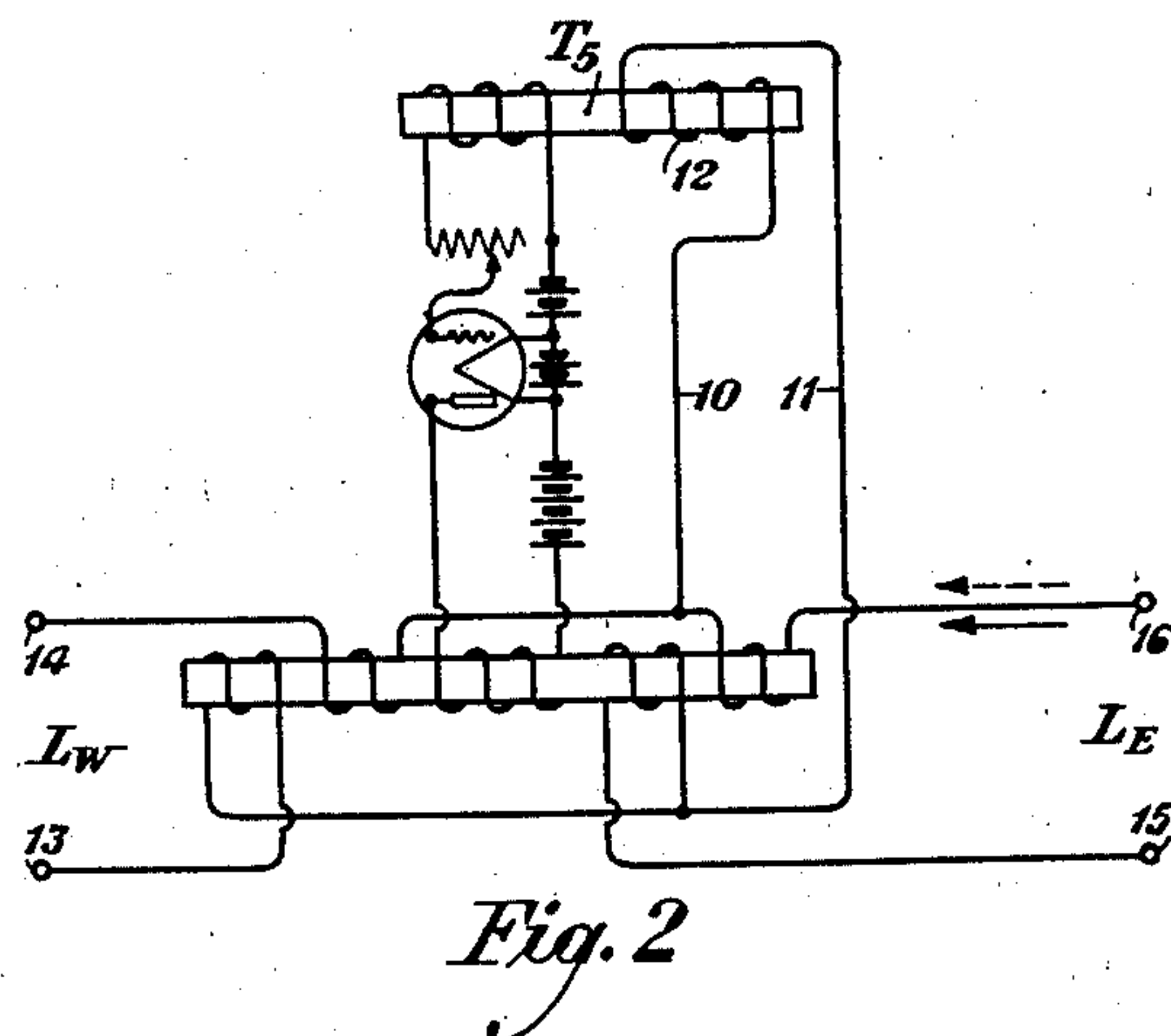


Fig. 2

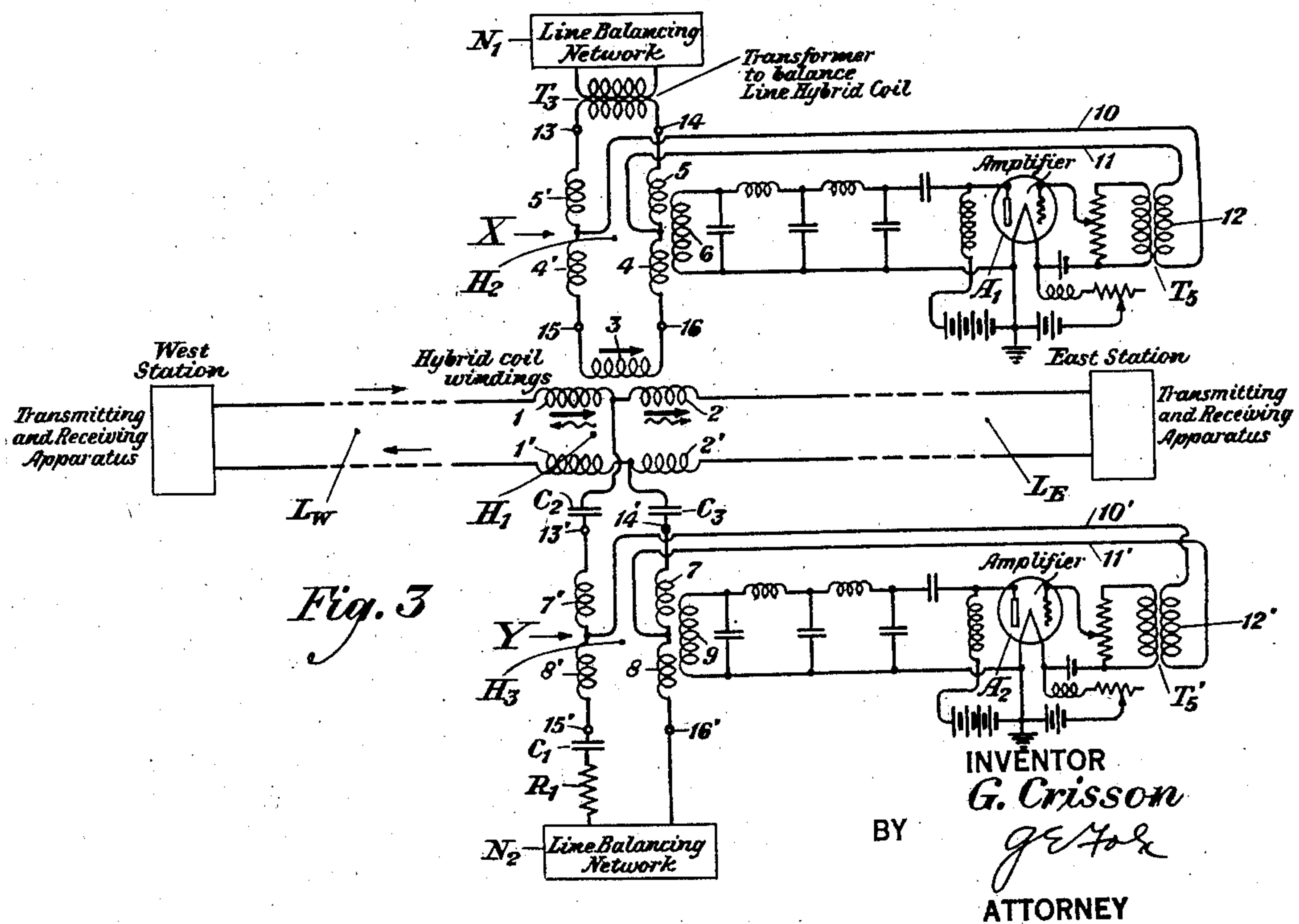


Fig. 3

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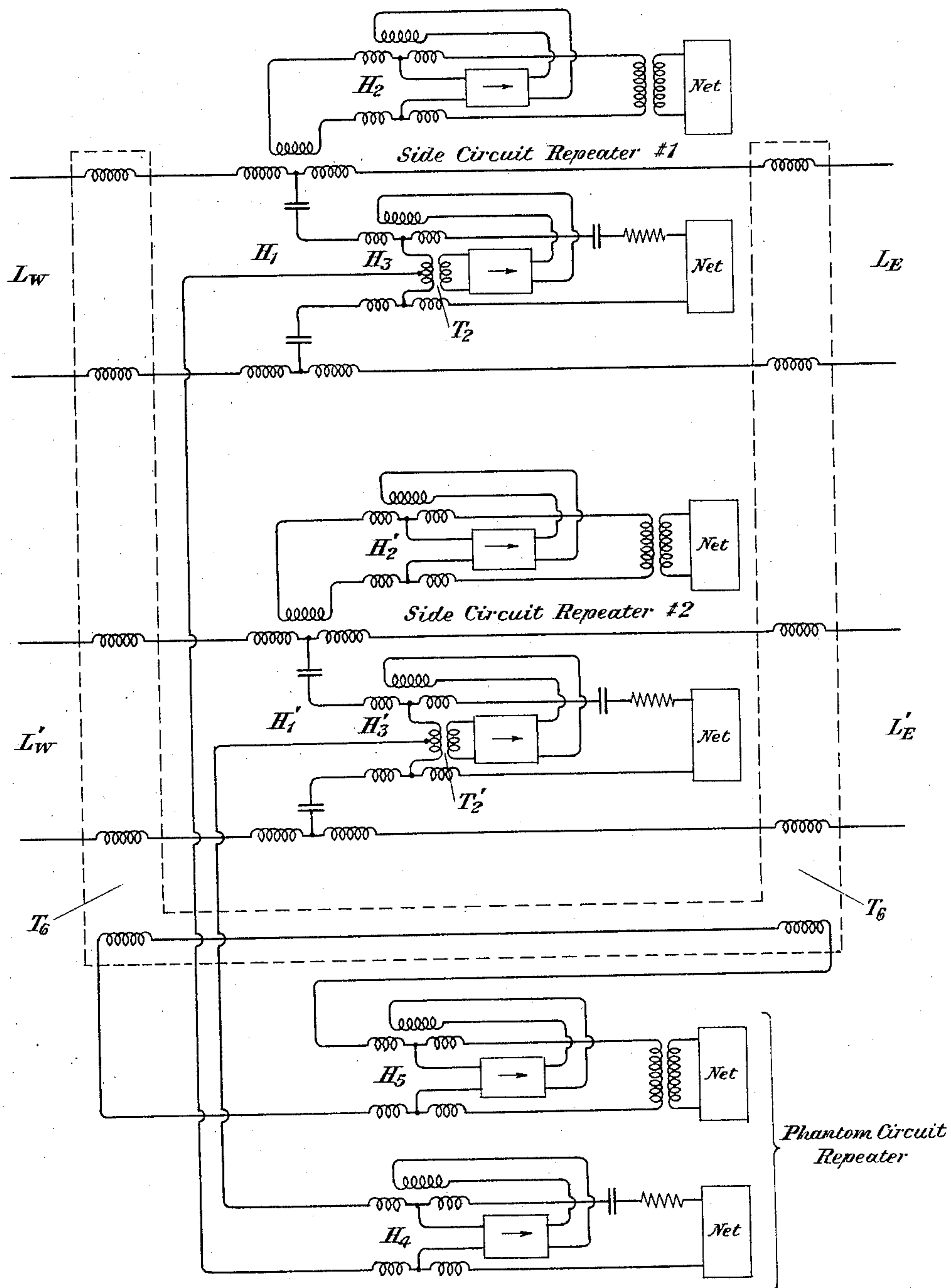


Fig. 4

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REPEATER SYSTEM

Application filed June 7, 1928. Serial No. 283,639.

This invention relates to repeaters for use in signaling systems, and particularly to a form or repeater circuit in which two 21-type repeater circuits are so associated with the line circuit that there is a continuous metallic path from each conductor of the line on one side of the repeater to a corresponding conductor of the line on the other side of the repeater. Direct currents or alternating currents of a frequency too low to be amplified by the repeater may pass through these metallic paths without interfering with the action of the repeater with respect to waves of higher frequency and without requiring the use of compositing apparatus to permit the passage of such direct or low frequency alternating currents.

One property of this repeater circuit is that three of them may readily be connected with the line conductors of a phantom group so as to amplify the waves traversing either of the side circuits or the phantom without requiring the use of phantom repeating coils. Another useful property is that it does not transmit amplified waves back toward the transmitter and therefore, does not produce echoes other than those due to irregularities in the line.

This invention resides primarily in a repeater circuit comprising two 21-type repeater circuits associated with the line circuit by means of a hybrid coil or other suitable network which provides a substantially conjugate relation between the two 21-type circuits and between the parts of the line circuit lying on opposite sides of the repeater.

The way in which this invention may be carried out is described completely in the following paragraphs and the accompanying drawings of which Figure 1 is a simplified drawing of a 21-type repeater circuit; Fig. 2 shows a 21-type repeater circuit in greater detail; Fig. 3 is a diagram of a repeater circuit embodying this invention; and Fig. 4 shows three repeater circuits embodying this invention which are combined to form a phantom group repeater circuit.

Fig. 1 shows a 21-type repeater circuit such as is well known in the art. This circuit includes a hybrid coil, or three-winding trans-

former H, two of whose windings 1, 1' and 2, 2' are connected in series between the two parts L_w and L_e of a transmission circuit such as, for example, a telephone line. The input terminals of an amplifier A of any suitable type are connected across the line circuit at the junctions between the windings 1, 1' and 2, 2'. The output terminals of the amplifier A are connected to the third winding 3 of the hybrid coil. A reversing switch S is included in either the output or input circuit of the amplifier. Assume now that a signal wave enters the repeater from the line L_w . If the input and output impedances of the amplifier are chosen to obtain the most efficient transmission into and out of the amplifier, as is well understood in the art, one-half of the energy of the wave is dissipated in the output circuit of the amplifier while the other half enters the input terminals and actuates the mechanism of the amplifier. Little, or none of the incoming wave will reach the line L_e . The action of the amplifier causes an amplified wave to be sent out of the repeater in both directions over the lines L_w and L_e . The arrival of the incoming wave at the repeater causes a current to flow at some instant from one line wire into one-half winding of the hybrid coil, for example 1, and out of the half winding 1' to the other wire as indicated by the heavy solid arrows. The emission of the amplified wave in both directions causes a current to flow in series through both line windings and both parts of the line as indicated, for example, by the dotted arrows.

Assuming first, for simplicity, that there is no phase shift in the amplifier, there is one position of the switch S in which the input and output currents flow in the same direction in the wires of the line L_w . Let this arrangement be designated as the direct connection. If now, the switch S is thrown to the opposite position, the direction of the output current is reversed so that this current flows in the opposite direction to the input current. Let this arrangement be designated as the reversed connection.

Now assume that the switch S is thrown to give the direct connection to the line L_w as indicated in Fig. 1, but assume further that a

wave is arriving over the line L_E and that at
 a given instant the input current is flowing
 into the half winding 2 from the line L_E and
 out of the half winding 2' to the line L_E . This
 current will flow in the same direction in the
 input circuit of the amplifier as the input cur-
 rent previously assumed as coming from the
 line L_W . The output currents will now flow
 in the direction indicated by the dotted ar-
 rows as before, but they are now flowing in
 the opposite direction to the input currents.
 From this it is evident that a 21-type circuit
 that is direct connected with respect to the
 line L_W will be reversed with respect to L_E
 and by throwing the switch S to the other po-
 sition, the 21-type circuit becomes direct with
 respect to L_E and reversed with respect to L_W .

Fig. 2 shows in greater detail a 21-type re-
 peater circuit including a vacuum tube am-
 plifier with the connections so arranged that
 the circuit is direct with respect to the line L_E
 and reversed with respect to the line L_W .

Fig. 3 shows one form of my invention. It
 comprises a hybrid coil H_1 , connected be-
 tween the two parts of a telephone line ex-
 tending to the two stations marked East and
 West stations, respectively. To the third
 winding 3 of the hybrid coil H_1 is connected
 a 21-type repeater circuit X which is direct
 connected with respect to the hybrid coil H_1 .
 A network N_1 and transformer T_3 are con-
 nected to the opposite terminals of the 21-
 type circuit to balance the hybrid coil H_1 and
 the two parts of the line. If this balance is
 good enough, the 21-type circuit cannot sing.
 Between the terminals 15—16 of winding 3
 and terminals 13—14 of transformer T_3 is
 connected the hybrid coil H_2 comprising the
 windings 4—4', 5—5' and 6. The input cir-
 cuit of the amplifier A_2 is connected with
 the junction points of the windings 4—4'
 and 5—5', the connection including the trans-
 former T_5 ; and the output circuit of the
 amplifier is connected with the winding 6.

A second 21-type repeater circuit Y is con-
 nected to the bridge points of the hybrid coil
 H_1 through the condensers C_2 and C_3 . The
 condenser C_1 , resistance R_1 , and the network
 N_2 are connected to the opposite terminals
 of the 21-type circuit Y to balance the con-
 densers C_2 and C_3 , the resistance of the line
 windings 1, 1' and 2, 2' of the hybrid coil
 H_2 and the lines L_W and L_E . The 21-type
 circuit Y is reversed with respect to the
 hybrid coil H_1 . Between the terminals
 13'—14' of the condensers C_2 and C_3 and the
 terminals 15'—16' associated with the net-
 work N_2 the condenser C_1 and resistance
 R_1 is connected the hybrid coil H_3 compris-
 ing the windings 7—7', 8—8', and 9. The
 input circuit of the amplifier A_2 is connected
 with the junction points of the windings
 7—7' and 8—8', the connection including the
 transformer T_5 ; and the output circuit of

the amplifier is connected with the wind-
 ing 9.

Now let a wave arrive at the hybrid coil
 H_1 over the line L_W . At a given instant let
 the current flow from the line L_W into the half
 winding 1 of the hybrid coil and from the
 half winding 1' to the line L_W as indicated
 by the light straight arrows. This current
 flows in the two 21-type circuits which in
 turn cause amplified currents to flow in their
 own circuits and in the lines. Due to its di-
 rect connection the 21-type repeater X causes
 an amplified current to flow at the terminals
 15, 16 in the same direction as the input
 current. This amplified current is repeated
 by the hybrid coil H_1 and flows into the two
 parts of the line as indicated by the solid
 heavy arrows.

Since the 21-type circuit Y is in reversed
 connection with the line, its amplified cur-
 rent flows at the terminals 13', 14' in the op-
 posite direction to the input current. In
 the line this current takes the directions indi-
 cated by the wavy arrows. It will be ob-
 served that the output currents flow in the
 same direction in the line L_E reinforcing each
 other, while in the line L_W extending toward
 the source of the waves, the output currents
 flow in opposite directions and tend to annul
 each other.

In this way the complete repeater of this
 invention transmits an amplified wave to-
 ward the listener, but by properly adjust-
 ing the gains of the two 21-type repeaters,
 the waves that tend to travel toward the
 speaker are completely cancelled out so that
 no echoes are produced.

Similarly, if a wave reaches the repeater
 over the line L_E , causing a current that flows
 into the half winding 2 of the hybrid coil
 H_1 and out of the half winding 2', the out-
 put current from the 21-type circuit X will
 be reversed in direction while that from the
 21-type circuit Y will flow in the same di-
 rection as before. The output waves will now
 reinforce each other in the line L_W and cancel
 out in the line L_E . A repeater built in ac-
 cordance with this invention will therefore
 amplify waves reaching it from either direc-
 tion over the line and send the amplified
 wave toward the receiving end of the line
 without returning echoes toward the source.

In the foregoing discussion it was assumed,
 for simplicity, that there was no phase shift
 in the process of amplification so the am-
 plified waves were strictly in phase with or
 in opposition to the incoming wave. It will
 be observed, however, that if equal phase
 shifts do occur in the two 21-type circuits, the
 output currents will still add up in phase
 or oppose each other as before, hence phase
 shifts do no harm provided they are equal
 in the two 21-type circuits. It was also as-
 sumed that the 21-type circuits X and Y were
 directly and reversely connected, respec-

tively, with respect to the lines but it will readily be seen that if Y is directly and X reversely connected with the lines, the invention will still operate in the manner described, since both output waves will be reversed in direction and the reinforcement of the desired wave and cancellation of the echo will occur as before.

The phase shift introduced by the fact that the inductance of the hybrid coil H_1 is not infinite is in the same direction as that introduced by series condensers C_2 and C_3 and varies in the same way with frequency; hence by choosing suitable capacities for these condensers with respect to the inductance of the hybrid coil H_1 and the impedance of the lines, these phase shifts may be equalized. The condensers C_2 and C_3 also serve to prevent the passage of direct or low frequency alternating currents into the 21-type circuit Y; consequently there is an uninterrupted and unshunted path for such currents through the line windings of the hybrid coil H_1 from the line L_W to L_E . This avoids the necessity for using compositing apparatus to provide a path for such currents around the repeater.

Fig. 4 shows how three repeater circuits working in accordance with this invention may be assembled in a phantom group so that the waves traversing each side and the phantom circuit may be amplified without interference with each other and without using phantom repeating coils. As in the arrangement of Fig. 3, the metallic continuity of the several line conductors of this phantom group is preserved through the repeater circuit.

In this figure, L_W and L_E represent sections of a line, which are connected with terminals of the hybrid coil H_1 . A twin 21-type repeater, designated side circuit repeater No. 1, is connected with the said line sections through the hybrid coil H_1 . Similarly, L_W' and L_E' are sections of another line connected with terminals of the hybrid coil H_1' through which another twin 21-type repeater, designated side circuit repeater No. 2, is connected with the said line sections. The said side circuit repeaters differ from that shown in Fig. 3 only in the manner in which the amplifying elements are associated with the hybrid coils H_3 and H_3' . In Fig. 3, a direct connection is shown, whereas in Fig. 4 the said elements are connected by means of the transformers T_2 and T_2' , respectively. This affords means for connecting with the lines L_W-L_E and $L_W'-L_E'$ one of the 21-type repeaters of the phantom circuit repeater. This is done by connecting the midpoints of the primary windings of the transformers T_2 and T_2' with the terminals of the hybrid coil H_4 associated with the bridged 21-type repeater that constitutes one of the units of the twin 21-type repeater of the phantom circuit. The other 21-type repeater of the

phantom group is connected with the conductors of the line circuits by means of the transformer T_6 comprising a plurality of windings upon the same core. One winding (shown in two sections) is connected with the terminals of the hybrid coil H_5 and the others are individual to and connected with the conductors of the sections of the said lines. The phantom circuit repeater simulates the side circuit repeaters and operates in substantially the same manner. It will therefore be apparent that by means of three 21-type repeaters, arranged in the manner shown in Fig. 4, it is possible to amplify the waves traversing both side circuits and also the phantom circuit without introducing interference and without rendering the circuit discontinuous for direct currents, which would result if phantom coils were employed.

While this invention has been disclosed as embodied in particular forms, 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. A repeater comprising a hybrid coil inserted between the two parts of a transmission circuit extending in opposite directions, a directly connected 21-type circuit and a reversely connected 21-type circuit, both of which are associated with the line through the hybrid coil.

2. In a repeating system, the combination with a transmission circuit of a directly connected 21-type circuit in series relation therewith, a reversely connected 21-type circuit in parallel relation with the transmission circuit, and means for effecting the said series and parallel relations.

3. In a repeating system, the combination with a transmission circuit of a directly connected 21-type circuit in series relation therewith and a reversely connected 21-type circuit in parallel relation with the transmission circuit.

4. In a repeating system, the combination with a transmission circuit of a 21-type circuit in series relation therewith, a second 21-type circuit in parallel relation therewith, one of said 21-type circuits being directly and the other reversely connected with respect to the transmission circuit, and means for effecting the said series and the said parallel connections.

5. In combination, a transmission circuit, a hybrid coil interposed between the parts thereof extending in opposite directions, a first 21-type circuit connected in series relation with the transmission circuit through the hybrid coil, a second 21-type circuit connected in parallel with the transmission circuit at the bridge terminals of the hybrid coils, one of said 21-type circuits being directly and the other reversely connected with respect to the transmission circuit, condens-

ers interposed in series between the said second 21-type circuit and the said hybrid coil, a network associated with each 21-type circuit adapted to balance the transmission circuit, the hybrid coil and the condensers, and means for adjusting the gains of the two 21-type circuits while keeping the gains equal.

6. The method of amplifying signaling waves traversing a transmission circuit, which consists in impressing the said waves simultaneously upon two 21-type repeater circuits, impressing the amplified waves from one 21-type circuit upon the sections of the transmission line on both sides of the repeater in series, and impressing the amplified waves from the other 21-type repeater upon the said sections in parallel.

7. The method of amplifying signaling waves traversing a transmission circuit, which consists in impressing the said waves simultaneously upon two 21-type repeater circuits, impressing the amplified waves from one 21-type circuit upon the sections of the transmission line on both sides of the repeater in series, and impressing the amplified waves from the other 21-type repeater upon the said sections in parallel, controlling the degree of amplification of the said 21-type repeaters so that the amplified waves from both repeaters are of the same magnitude, and directing them so that they reinforce each other in that part of the transmission circuit extending toward the receiver and annul each other in that part of the transmission circuit that extends toward the transmitter.

8. A phantom group of repeaters comprising three repeaters each of which consists of a hybrid coil and two 21-type circuits, the windings of each hybrid coil associated with a side circuit being inductive to that side circuit and non-inductive to the phantom and the windings of the phantom hybrid coil being inductive to the phantom and non-inductive to both side circuits, two 21-type circuits associated with each hybrid coil, one being in series relation and the other in parallel relation with the corresponding side or phantom circuit, one of said 21-type circuits being directly and the other reversely connected with respect to the hybrid coils, networks associated with each 21-type circuit adapted to balance the side or phantom circuit and the hybrid coil to which the 21-type circuit is connected, condensers in each conductor which extend from either conductor of each side circuit to the other conductor of the said side circuit, and means for adjusting the gain of each 21-type circuit while keeping equal the gains of the two 21-type circuits associated with each hybrid coil.

9. The method of amplifying signaling waves traversing a transmission circuit, which consists in dividing the waves into two parts, amplifying the said parts and reimpres-

trolling the degree of amplification and the direction of application of the said parts to the said transmission circuit so that they reinforce each other in that part of the circuit extending toward the receiver and annul each other in that portion of the line extending toward the transmitter.

10. A repeater for connection with a line circuit comprising a three-winding transformer and two 21-type repeater circuits, the said transformer having two windings connected with said line and the third winding connected with one of the said 21-type circuits, the other 21-type circuit being bridged across the midpoints of the line windings of the said transformer.

In testimony whereof, I have signed my name to this specification this 5th day of June, 1928.

GEORGE CRISSON.