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H. NYQUIST

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POLAR DUPLEX TELEGRAPH SYSTEM

Filed Dec. 17, 1931

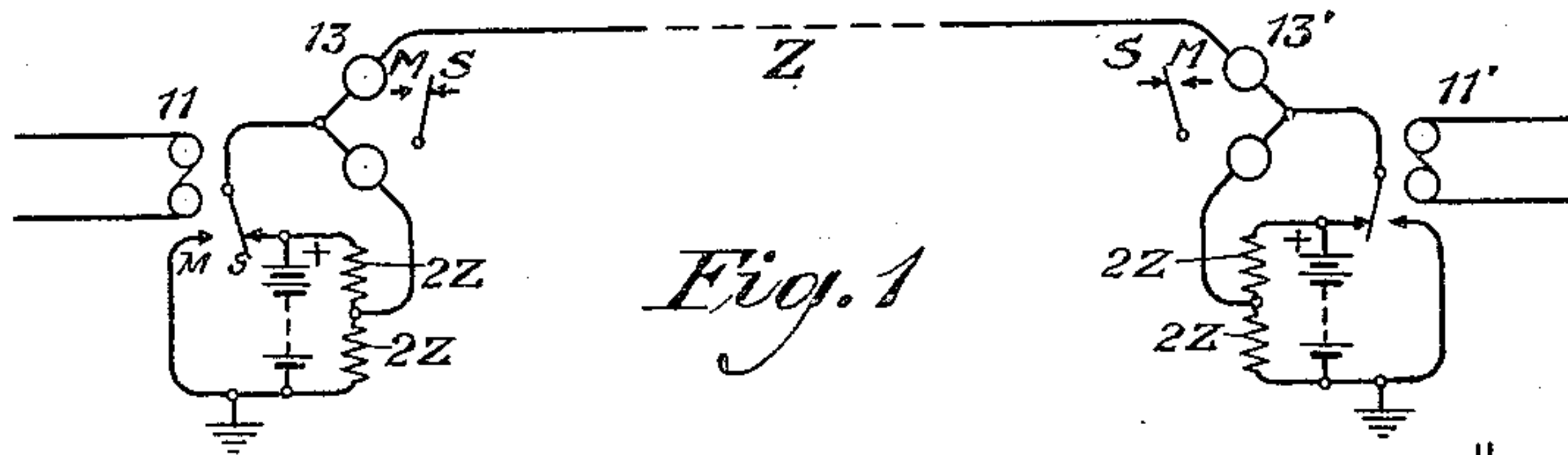


Fig. 1

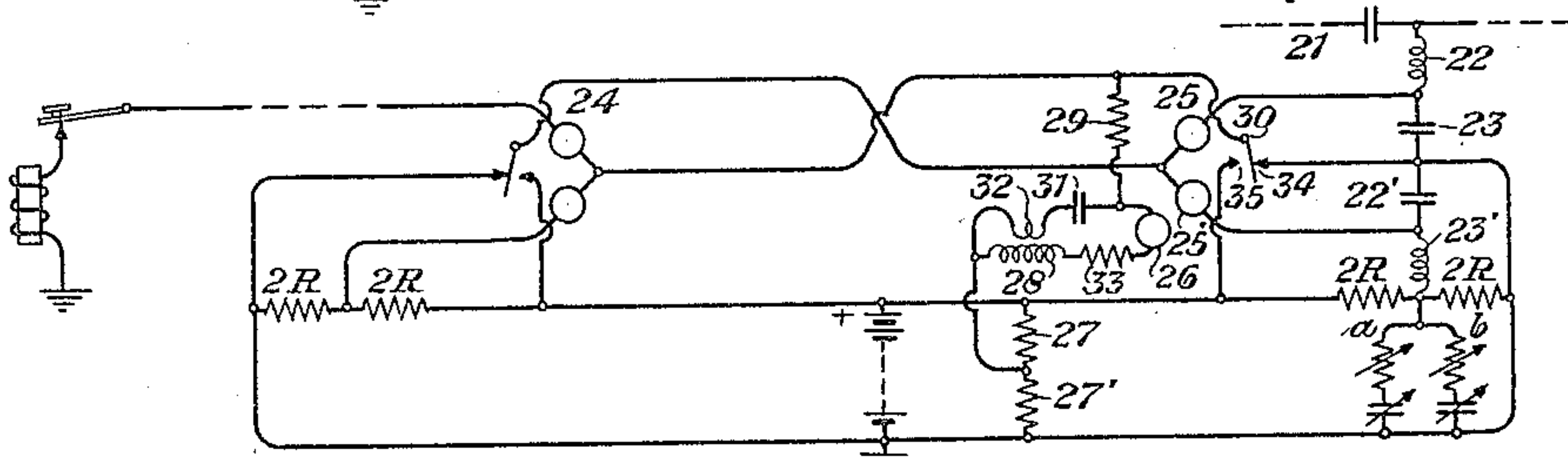


Fig. 2

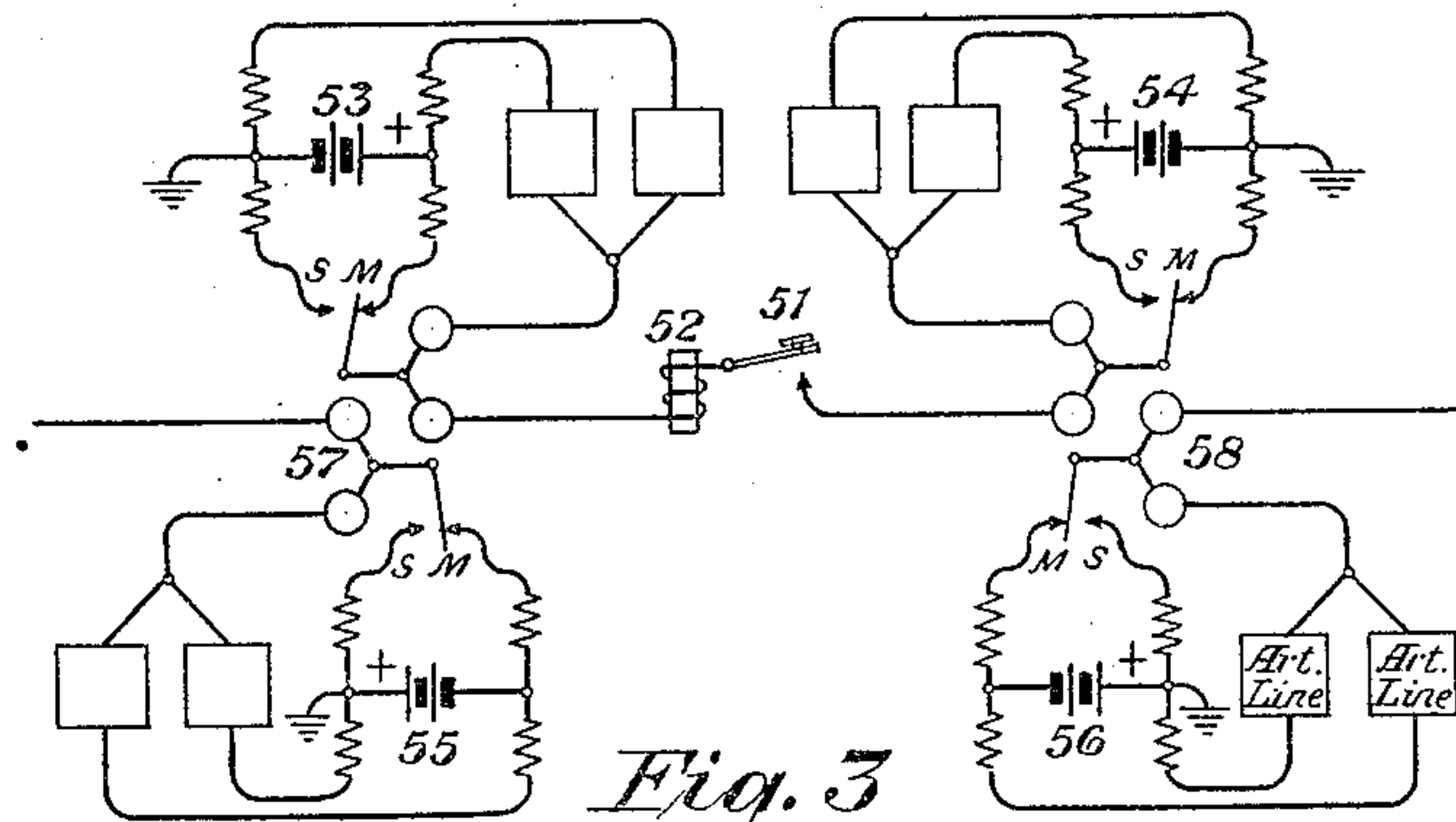


Fig. 3

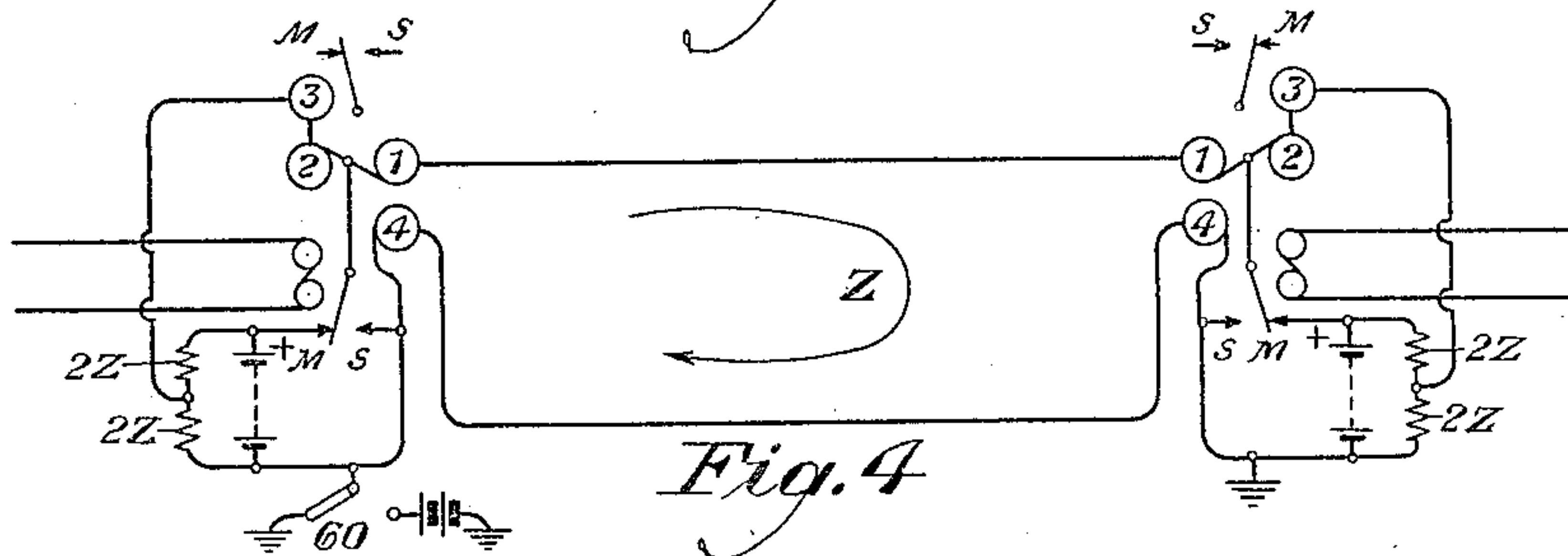


Fig. 4

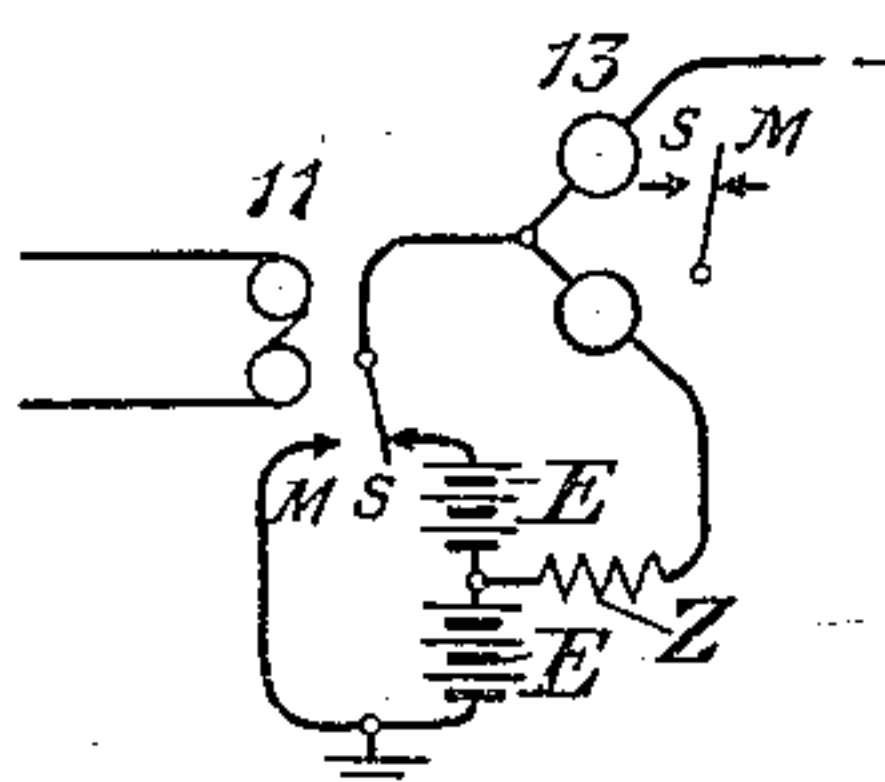


Fig. 5

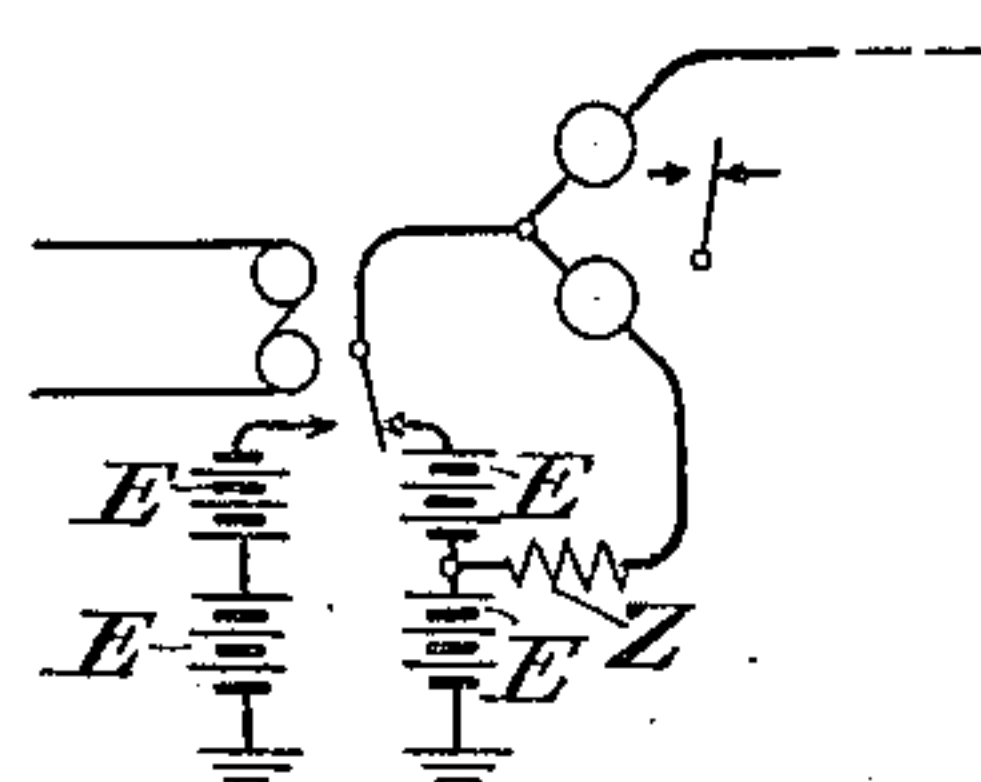


Fig. 6

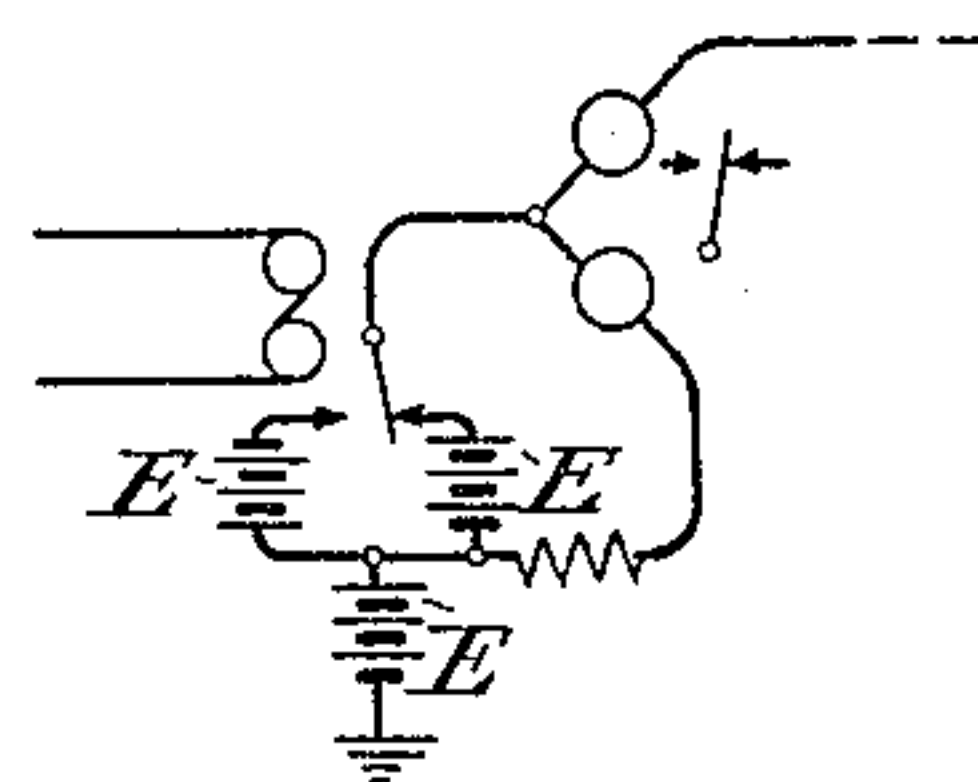


Fig. 7

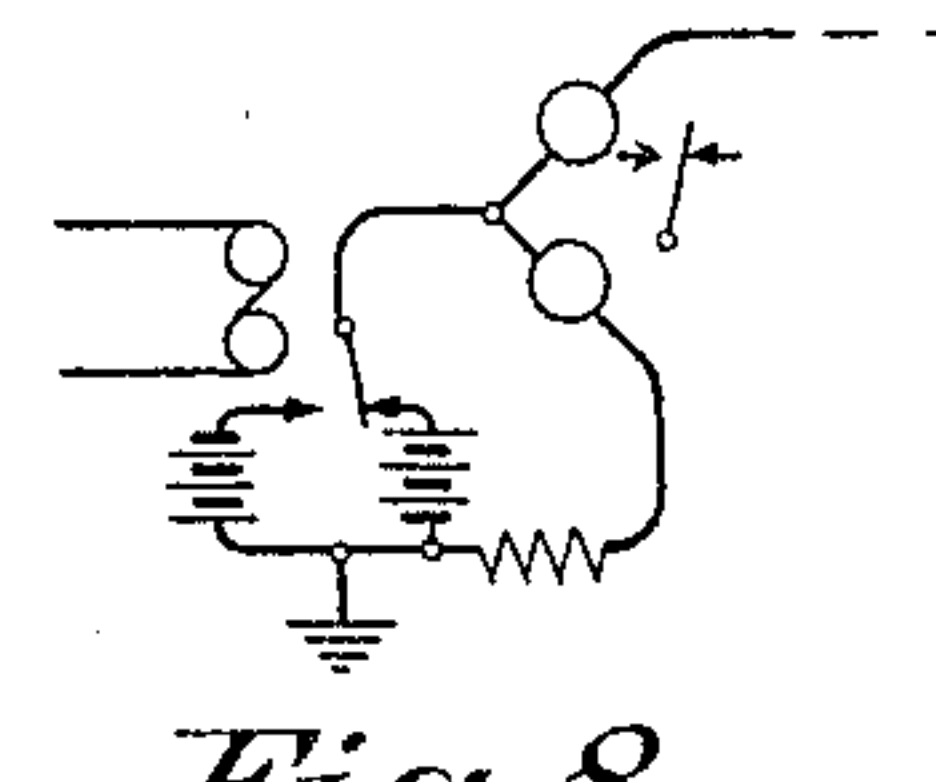


Fig. 8

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POLAR DUPLEX TELEGRAPH SYSTEM

Application filed December 17, 1931. Serial No. 581,745.

It is among the objects of my invention to provide a new and improved polar duplex telegraph system employing a reduced number of batteries, and under some circumstances the system may employ only a single battery at a station on the line. Another object of my invention is to provide in this connection for operating the circuit on the "upset half duplex" principle. Still another object has relation to incorporating the "vibrating circuit" feature with the receiving relays so as to improve transmission. My invention may be involved in end apparatus for such a system, or a repeater between a long line and a terminal loop, or a repeater at an intermediate point on a long line, with or without means for signaling to and from a station at such a repeater. All these objects of my invention and other objects and advantages will be made apparent in connection with the following disclosure of a limited number of specific examples of practice according to the invention. It will be understood that the following description has relation principally to these particular examples of the invention and that its scope will be indicated in the following claims.

Referring to the drawing, Figure 1 is a diagram showing a line with sending and receiving apparatus at its ends according to my invention; Fig. 2 is a diagram showing a two-way repeater between a long line on one side and a local circuit on the other side, and incorporating the "vibrating circuit" feature; Fig. 3 is a diagram showing a repeater adapted for operation between two long line sections and with a key and sounder for an operator at the repeater, on the upset half duplex principle; Fig. 4 is a diagram showing how my invention may be embodied in an all-metallic circuit; and Figs. 5, 6, 7 and 8 are a series of diagrams to facilitate explanation of Fig. 1.

Referring to Fig. 1, this shows a long line of impedance z with ground return and with terminal stations adapted for duplex operation. In accordance with my invention there is only a single battery at each terminal station. The system is shown in its condition when there is no sending. At such time each

sending relay 11 holds its armature on the spacing contact and the positive poles of the batteries at the ends of the line are applied to the line and buck each other on the line so that no current flows in the windings 13 and 13'. But current flows from each battery (plus) through the spacing contact of the associated sending relay and the lower winding of the receiving relay back through the lower impedance $2z$ to battery (minus). This current holds the associated receiving relay armature on its spacing side.

To establish the mode of operation of the system of Fig. 1, let it be transformed successively as shown in Figs. 5, 6, 7 and 8 for the left end, the right end to correspond at each stage. The impedance of the battery being negligible, Fig. 5 is equivalent to Fig. 1, the two parallel impedances each $2z$, being replaced by the single series impedance z , and connection being made at the midpoint of the battery instead of equally at its ends. In Fig. 6, as compared with Fig. 5, two equal batteries E bucking each other have been introduced between ground and the marking contact of relay 11 and hence the equivalence of these figures is apparent. In Fig. 7, the parallel ground connected batteries E have been replaced by a single battery E , hence presenting the same electromotive force, and in Fig. 8 this single lowermost battery E of Fig. 7 has been omitted since it can play no part in the operation of the circuits. It will be remembered that in each stage of Figs. 5 to 8, there is a corresponding arrangement at the opposite end of the line. Hence the ground connected battery E in Fig. 7 bucks a like ground-connected battery at the opposite end of the line whenever such connections are made that either battery becomes connected in a circuit that comprises the line. Neither of these ground connected batteries can have any effect in the local circuit at its end of the line because there is only the single ground connection at that end. Hence these two batteries at the ends of the line can be omitted, thus passing from Fig. 7 to Fig. 8.

But Fig. 8 will operate on the full polar duplex principle as is well known, and therefore the corresponding system of Fig. 1 will op-

erate likewise. Hence, it will not be necessary to follow through all the details of marking or spacing at either or both ends of the circuit; they are determined by the system as diagrammed in Fig. 1, and they give full duplex operation.

It will be noticed that the artificial line consists of two portions each of impedance $2z$. But these portions are connected to the balancing line in parallel so that their impedance in that relation has the value z , thus giving the proper value for balancing the line. It has been mentioned already that the impedance of the battery is negligible in this connection. Thus, according to my invention, a single battery serves at either end for full or half duplex operation of the system of Fig. 1.

In Fig. 2 there is a terminal repeater to which a long line comes in from the right. This part is involved in composite operation and the voice frequency currents are taken off on the branch designated 21. The usual telegraph branch of a composite set consisting of series inductance 22 and condenser 23 in a branch path to ground are shown, and to the left of these is a terminal telegraph station adapted for sending and receiving on the long line to the right. The coil 22 and condenser 23 for compositing are duplicated at 22' and 23' in connection with the artificial line. This artificial line consists of the two resistances, each of value $2R$, connected as shown, and in combination having the proper direct current impedance value R . The timing members a and b employ capacities and resistances of the same values as would normally be used in the case of an ordinary two-battery arrangement. These timing members have zero admittance to direct current and hence it is not necessary to make them a part of the potentiometer consisting of the two resistances, each $2R$, in series.

In the case of Fig. 2 the relay 24 is sending relay and 25—25'—26 is a receiving relay. This receiving relay has the two normal coils 25 and 25' of a differential duplex relay and, in addition, the vibratory circuit winding 26 connected as shown. When the circuit is idle, as shown in Fig. 2, a current flows from battery (plus) through the resistance 27, coil 28, resistance 33, relay winding 26, resistance 29, armature 30 and right-hand contact 34 of relay 25—25'—26, and back to the grounded side of the battery. This current in the coil 26 alone has a tendency to break the contact at 34, but the tendency is overcome by the normal current in the winding 25' in the artificial line branch. The potential drop through coil 28, resistance 33 and winding 26 establishes a corresponding static charge in condenser 31. When a received spacing impulse coming in over the long line at the right breaks contact at 34, the current in the cir-

cuit of winding 26 is interrupted at 34, but the self inductance of windings 28 and 26, and the mutual inductance effect in winding 32 and the condenser discharge at 31 all act in the same direction around the closed circuit of these elements and sustain a transient current through winding 26 until after armature 30 of relay 25—25'—26 makes the contact 35. This current in winding 26 therefore speeds the shift of the armature 30 and increases the certainty of its contact on the other side at 35. However, as soon as this contact is made at 35, the battery becomes effective in the circuit from battery (plus) through contact 35, armature 30, resistance 29, parallel paths 31—32 and 26—33—28, resistance 27' to battery (minus). The corresponding current in 26 tends to break the contact at 35 but this tendency is overcome by the current in winding 25. The condenser 31 charges oppositely compared with its former charge, and the apparatus is now in the condition for armature 30 on contact 35 corresponding to armature 30 or contact 34 as described above. The time constants for the elements involved are adjusted so that reception is substantially quickened by the vibrating circuit. It is to be observed that the same battery is employed for the vibrating circuit as for the remaining elements of the system. This explanation for Fig. 2 will make its complete operation fully apparent in view of the explanation previously given for Fig. 1.

In Fig. 3 I have shown a repeater with an interposed key 51 and sounder 52. This system is connected up to operate the local circuit as an upset half-duplex system. The consolidation of batteries has not been carried as far as in Figs. 1 and 2, and the batteries 53 and 54 for the short line comprising parts 51 and 52 may be of different strength from the batteries 55 and 56 for the extended lines each way. The normal condition when no signals are being sent is for all relays to be on their marking contacts, and current flows on the short line through 51 and 52, the circuit being from ground through battery 53, marking contact of relay 57 and elements 52, 51, marking contact of relay 58, and ground. As long as key 51 is closed the system can be worked either way through from one distant end to the other, and the signals will be given on the neutral sounder 52. But at any time the operator at 51—52, may "break" with his key 51 and may send both ways therefrom with this key.

Fig. 4 shows a modified embodiment of my invention adapted for an all-metallic circuit. Here each receiving relay has four windings 1, 2, 3 and 4 connected in the circuits as shown. Practically all the operating current would flow through winding 1 of the receiving relay and the ground connection, and it is desirable to obtain the advantage of the additional wire to serve as a neutralizing circuit for ground

potential, cross-fire effects, etc. Hence, one winding 4 of the receiving relay at each end is connected in series in the additional wire. Then another winding 3, identical with 4, must be connected in the artificial line to establish complete duplex balance.

By throwing the switch 60, a ground potential can be interposed at one end. With the windings 1 and 4 connected series aiding for transverse signaling currents, no material effect on the relays will be produced by the longitudinal currents due to this interposed potential. This shows that the system represented by Fig. 4 with switch 60 as shown, will not be affected to give false signals by a difference of potential to ground at the ends.

I claim:

1. In a polar duplex telegraph system, a geographically extended line, an artificial line to balance the first mentioned line, said artificial line consisting of two networks in parallel with each other, a battery connected in series with one of said networks, each of said networks having an impedance twice that of the geographically extended line, a receiving relay associated with both said lines, and a sending relay associated with said battery.

2. In a polar duplex telegraph system, a geographically extended line, an artificial line to balance the first mentioned line, said artificial line consisting of two networks in parallel with each other, a battery connected in series with one of said networks, each of said networks having an impedance twice that of the geographically extended line, a receiving relay associated with both said lines and a sending relay associated with said battery, the armature of said sending relay being permanently connected with the windings of said receiving relay and both said lines in balanced relation, and there being two opposite alternative contacts for said armature, one contact being connected through the battery to ground and the other contact being connected directly to ground.

3. In combination, a line of a certain impedance, a battery at one end of the line, said battery being grounded at one of its ends, a network connected across the ends of the battery, a receiving relay having two windings, one connected on one side to the said line and the other winding connected on one side to the midpoint of said network, the parts of the network on either side of said midpoint each having an impedance twice that of the line, and a sending relay having its armature connected with the remaining sides of said receiving relay windings, said windings being in parallel with respect to outgoing or sending currents.

4. In combination, a line of a certain impedance, a battery at one end of the line, said battery being grounded at one of its ends, a network connected across the ends of the bat-

tery, a receiving relay having two windings, one connected on one side to the said line and the other winding connected on one side to the midpoint of said network, the parts of the network on either side of said midpoint each having an impedance twice that of the line, a sending relay, a contact for the armature of said sending relay connected to the non-grounded end of the battery and an opposite contact connected directly to ground.

5. A system as defined in claim 1 having a potentiometer across said battery, a vibrating circuit, and a winding in said circuit on said receiving relay, said circuit being connected to the midpoint of said potentiometer.

6. A combination as defined in claim 3 having a local line connected with said sending relay, and a key and sounder in said local line, the batteries and relay contacts being poled for upset half duplex operation of the local line.

7. In a polar duplex telegraph system, a two-conductor all-metallic line, an artificial line to balance the first mentioned line, said artificial line comprising two networks in parallel, each of impedance twice that of the first mentioned line, a battery connected across said networks in series, a receiving relay having windings respectively in one side of the first mentioned line and in the artificial line, a sending relay controlling the connections for said battery and respective equal additional windings on said receiving relay in the remaining side of said first mentioned line and in the artificial line.

In testimony whereof, I have signed my name to this specification this 15th day of December 1931.

HARRY NYQUIST.