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J. J. O'CONNELL.

APPARATUS FOR AMPLIFYING OR REINFORCING TELEPHONE CURRENTS.

APPLICATION FILED AUG. 22, 1903.

NO MODEL.

Fig. 1.

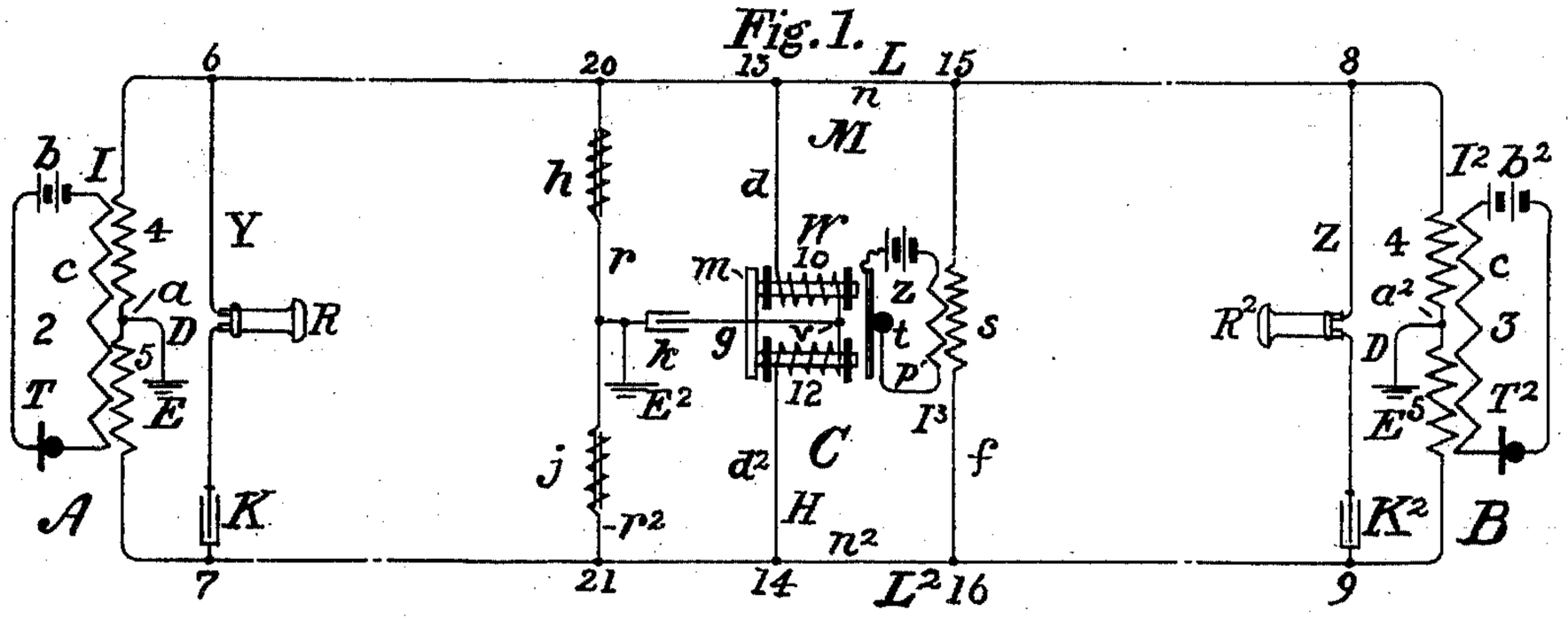
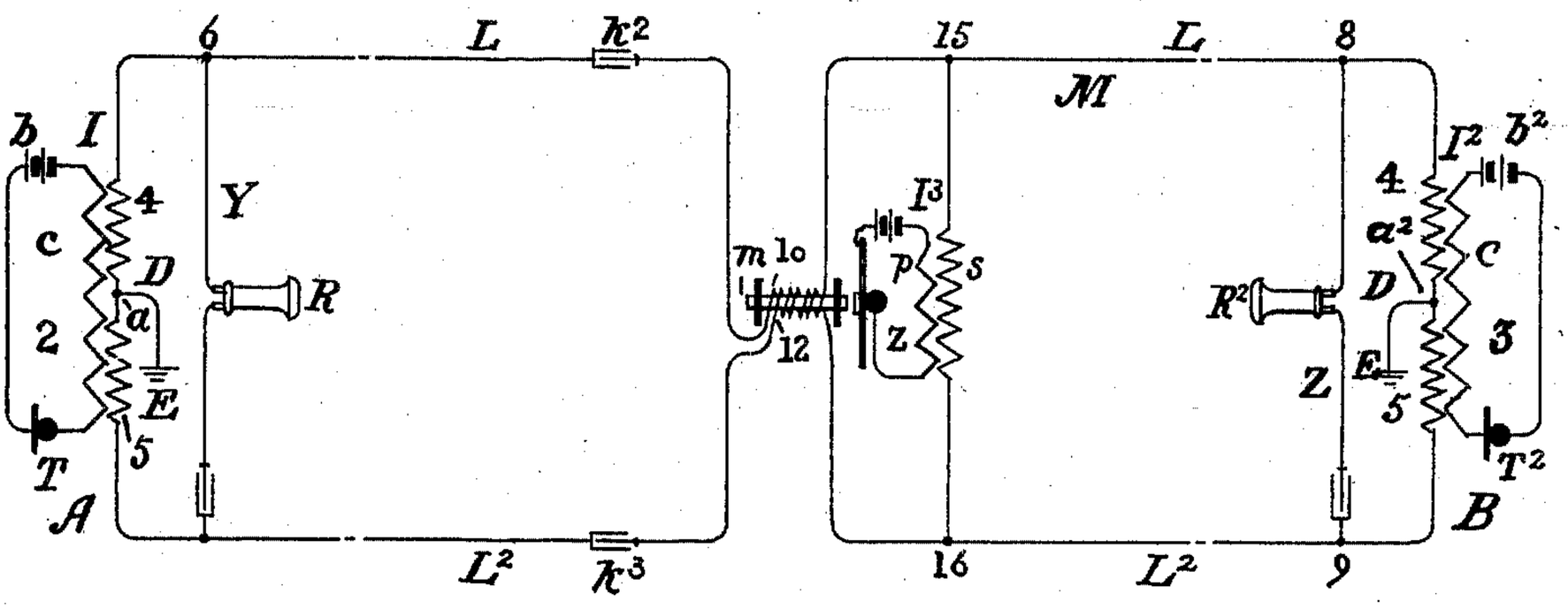


Fig. 2.



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR AMPLIFYING OR REINFORCING TELEPHONE-CURRENTS.

SPECIFICATION forming part of Letters Patent No. 760,143, dated May 17, 1904.

Application filed August 22, 1903. Serial No. 170,440. (No model.)

To all whom it may concern:

Be it known that I, JOSEPH J. O'CONNELL, residing at Chicago, in the county of Cook and State of Illinois, have invented certain Improvements in Apparatus for Amplifying or Reinforcing Telephone-Currents, of which the following is a specification.

This invention relates to telephonic circuits and apparatus, and in particular to arrangements of conductors and appliances designed for the amplication or reinforcement of telephone-currents in long circuits for the more perfect operation of the receiving instruments at the final receiving-station.

As is well known, the attenuation of the talking-currents in long telephone-circuits, attributable to various causes, is very considerable, so that the volume of the sounds or conversation reproduced by the receiving-telephone at the receiving-station is very faint compared with that of the said sounds or conversation as originally transmitted.

The object of my improvement is to so reinforce the originally-transmitted voice-currents that they shall be enabled to affect and operate the receiving-telephone at the receiving-station of a long circuit with substantially the same vigor as if the circuit connecting the transmitting and receiving telephones were very short.

To this end my invention consists in combining the two wires or conductors of any telephone-circuit with terminal grounding attachments whereby they are enabled to constitute in series a metallic main circuit and in parallel an earth-completed circuit. At each terminal station the transmitter is in the said earth-completed circuit, and the receiver is in the metallic circuit or a bridge thereof, together with a condenser. The transmitter at each terminal station is enabled to develop its currents in the said earth-completed main circuit through the medium of an induction-coil which has two secondary windings, one in each main conductor, the earth connection at each terminal station being between these. When either station is transmitting, these secondary windings at the receiving-station are in series and together form an impedance-coil tending to shunt the telephone-current through the receiver at said station, the said windings offering maximum impedance to voice-currents flowing in the metallic circuit.

At an intermediate point or station is a repeating, reinforcing, or renewing apparatus having its actuating-magnet in the grounded or earth-completed circuit extending between either transmitting-station and the said intermediate point and a transmitter operated by said magnet and acting to repeat into or transfer to the metallic circuit and the receiver included therein the voice-currents of said grounded circuit. The said actuating-magnet is responsive to the operation of the transmitter at either end station, and the said transmitter operated thereby develops renewed currents for the operation of either receiver. The said transmitter is itself preferably in a local circuit, together with a battery, and acts upon the metallic main circuit, which includes the receiver, through the medium of an induction-coil whose primary winding is also in said local circuit and whose secondary is in a bridge between the two main conductors of the metallic main circuit. The actuating-magnet has two exciting-helices in earth branches of the two main conductors, respectively, and these are coöperatively connected as respects currents flowing in the earth-completed main circuit, but are opposed to one another as respects currents flowing in the metallic circuit, a condenser being placed in each earth branch or in the common earth connection of the two. In parallel with the said earth branches are other earth branches containing coils of low resistance and high inductance which operate to divert telegraphic or other low-frequency induction-currents from the actuating-magnet of the repeating device, but which do not divert the voice-currents.

In the drawings which accompany and illustrate this specification, Figure 1 is a diagram of a preferred arrangement of circuits and apparatus wherein my invention may be embodied, and Fig. 2 is a similar diagram of a modification thereof.

In the said drawings, L and L^2 are main conductors extending between two terminal stations A and B through an intermediate point or station C. These at the terminal stations are united at the points *a* and a^2 and provided with earth connections E. Thus the said main conductors in series constitute a metallic circuit M and in parallel conjunctively with said earth connections and earth-completed circuit D.

T T^2 are terminal-station transmitters connected in local circuits 2 3 with local batteries *b* b^2. I I^2 are the induction-coils of these transmitters, each such coil having a primary winding *c* in its appropriate local circuit, and two secondary windings 4 5, connected in the two main conductors L L^2, respectively, so that they are in parallel in the grounded circuit D and in series in the metallic circuit M. By this means the transmitters T T^2 are each enabled to impress upon or develop in the said grounded circuit and in the joint or parallel conductors thereof voice-currents intended for the operation of the receiver of the other terminal station. The said secondary windings 4 and 5 are connected one on each side of the terminal earth connections E and may be regarded either as two distinct secondary helices or as the two halves of a single secondary winding; but in either case they are in series in the metallic circuit M and must be so connected therein as to present maximum impedance to the currents thereof. In other words, they are to be wound or connected from one end to the other as a single electromagnetic helix in said metallic circuit M. By means of this arrangement the two secondary windings of the terminal induction-coil of the station which at any moment happens to be receiving are enabled to serve as an impedance-coil as regards incoming telephone-currents and to divert the said currents mainly through the station-receiver, the connection arrangement of which is now to be described.

R R^2 are the telephone-receivers of the terminal stations A and B and are connected in bridges Y Z of the metallic circuit M, or, in other words, the receiver R is connected in the bridge Y, extending from point 6 on main conductor L to point 7 on conductor L^2, while the receiver R^2 in a similar way is in the bridge-conductor Z, extending between points 8 and and 9 of conductors L and L^2. Thus while the transmitters T and T^2 are connected to operate in the main earth-completed circuit D the receivers R and R^2 are in bridges of the main metallic circuit M.

W is the reciprocal repeating or current-amplifying apparatus at an intermediate point or station C. This intermediate point may be located at any convenient distance from the transmitting-station; but since the majority of cases in practice would require reciprocal transmission, or, in other words, since the repeating apparatus as usually employed is required to properly respond to the operation of the transmitter of either terminal station indifferently and to retransmit the currents thereof to the receiver at the other terminal station, the said repeating apparatus is preferably placed at a point about equidistant from said terminal stations. Referring particularly to Fig. 1, *m* is the actuating-electromagnet of said repeating apparatus and is operatively associated with the main grounded or earth-completed circuit D. *t* is the telephone-transmitter of said apparatus, controlled and operated by said actuating-magnet and included in a suitable local circuit *z*, and I^3 is an induction-coil also belonging to said repeating apparatus, having its primary winding *p* in the local circuit *z* and its secondary winding *s* in a bridge *f* of the metallic main circuit M—that is, between main conductors L L^2 at any convenient points 15 16. Earth branches *d* d^2 extend at said intermediate station C from the main conductors L L^2, respectively, at points 13 and 14 to earth at E^2, and the required association of the actuating-magnet *m* with the main earth-completed circuit D is brought about by connecting the two exciting-coils 10 and 12 of said magnet in the said earth branches *d* and d^2, respectively, the common ground connection *g* of the branches *d* and d^2 being attached at a point *v* between the coils. Another way of viewing the said earth branches *d* d^2 is to regard them as forming a centrally-grounded bridge H of the metallic circuit M, extending between points 13 and 14 of the main conductors L L^2 and the coils 10 and 12 of the actuating-magnet, which may be either on different cores or different ends of the same core, as virtually forming independent magnets connected in the two parallel conductors of the grounded circuit D and also in the said bridge H of the metallic circuit M, the said coils being so wound or connected that they coöperate with one another in said grounded circuit and in respect to the operative currents developed therein by either terminal transmitter being therefore responsive to said transmitters and oppose one another in said metallic-circuit bridge, being neutral and inoperative in respect to the working currents of said metallic circuit or to such portion thereof as may leak through said bridge between the points 13 and 14. Since the said coils are, as stated, connected neutrally or in opposition as regards the metallic-circuit currents, their collective impedance is necessarily low and cannot be relied upon to prevent the possible leakage of the talking-currents of said metallic circuit through the bridge H or earth branches *d* d^2 in series between points 13 and 14; but to prevent such leakage I wind the said coils with many turns of fine wire to a sufficiently high resistance. The diaphragm or vibratory plate of the transmitter *t* is mounted in close proximity to the poles of the magnet *m*, forming an armature therefor to

be actuated thereby, and by this means talking-currents flowing in the grounded main circuit D and exciting the magnet *m* are enabled to develop themselves anew or reproduce themselves in the local transmitter-circuit *z*, and thus through the medium of the induction-coil I^3, whose secondary is in the bridge *f* of the metallic circuit M, they are inductively propagated with their vigor renewed in said metallic circuit. Since at any given moment the transmission is proceeding in one direction only—say from A to B—the two main conductors are virtually formed into an operative grounded circuit extending from earth connection E at the terminal station A to earth connection E^2 at the intermediate station C for the first half of the line and formed into an operative metallic circuit extending from the induction-coil I^3 at the intermediate station C to the receiving-telephone R^2 at the terminal station B. The said grounded circuit D may thus be traced: from earth at E to point *a*, where it splits into parallel conductors, one proceeding through secondary 4 of induction-coil I over conductor L to point 13, earth branch *d* and exciting-coil 10 of the magnet to the point *v* between the coils 10 and 12 and the other through secondary winding 5 of said induction-coil I and over main conductor L^2 to point 14 and by way of earth branch d^2 and the coil 12 of magnet *m* to the said point *v*, where the said parallel conductors reunite, continuing to earth at E^2 through the common earth connection *g*. The said metallic circuit is traceable as follows: from one end of the secondary winding *s* of induction-coil I^3 through one half of bridge *f* to point 15 of main conductor L, thence by said conductor to point 8, to bridge Z, receiver R^2, point 9, main conductor L^2, point 16, and the other half of bridge *f* to the other end of the induction-coil secondary *s*. Of course when the direction of transmission is reversed the grounded and metallic operative circuits are also reversed. The grounded or earth-completed circuit begins in that case at terminal station B, ends, as before, at the intermediate-station earth E^2, and, as before, includes in its parallel sides the coils 10 12 of the repeating-magnet *m*, while the metallic circuit, as in the former case, extends between the terminals of the secondary winding *s* of the induction-coil I^3, but leads through the receiver R at terminal station A.

The portions $n\ n^2$ of the main conductors L L^2 lying between points 13 and 15 of conductor L and between points 14 and 16 of conductor L^2 may be common to the currents of both grounded and metallic circuits. The actuating-magnet *m* of the amplifying or repeating apparatus is thus operated in a circuit, which having but one-half of the geographical length of the entire line, utilizing the earth as its return, and having a line conductor with double sectional area offers a resistance practically not more than one-eighth of that of an ordinary metallic circuit extending between the same two terminal stations and worked in the ordinary way. The said amplifying apparatus, moreover, is located at a central and neutral point of the line, and therefore will to a marked extent be free from inductive disturbance.

A condenser *k* is placed in the ground connection of the amplifying-apparatus-actuating magnet to prevent the passage of steady leakage-currents, and thereby forestall any changes in adjustment which otherwise might be caused by such currents. For the same reason condensers K and K^2 are also placed in the bridges Y and Z in series with the receivers R R^2.

Impedance-coils *h* and *j*, connected in independent earth branches $r\ r^2$, are associated with the amplifying apparatus at the intermediate station C, the said earth branches being extended from points 20 and 21 of main conductors L and L^2, respectively, to earth at E^2. These earth branches parallel the earth branches $d\ d^2$ of the actuating-magnet of said amplifying apparatus, and the impedance-coils *h* and *j* are wound to have a low resistance for the ready shunting or diversion from the actuating-magnet of intrusive inductive or conductive currents of steady or comparatively slow-changing character which may stray upon the main conductors from neighboring telegraphic or other systems and which might interfere with the normal operation of the amplifying apparatus. The inductance of said coils is, however, made high to prevent wastage of the voice-currents through them.

In the operation of this system, assuming A to be transmitting, voice-currents of like sign at any definite instant are developed by the two secondary windings 4 5 and pass out over both of the main conductors L L^2, which in parallel constitute the earth-completed circuit D, and through the coils 10 and 12 of the actuating-magnet *m* of the amplifying apparatus at the intermediate station C, also in parallel in said circuit D, and by earth return back to the transmitting-station. These grounded-circuit talking-currents excite the said actuating-magnet, which acting upon the renewing-transmitter *t* causes the same to develop facsimile talking-currents in its local circuit, which renewed currents are transferred, through the medium of the induction-coil I^3, to the bridge *f*, containing the secondary of said induction-coil, and thus to the metallic circuit M and the receiver-bridge Z for the operation of the receiver R^2. The same operation in reverse order will be carried on when B is transmitting to A. The renewed or amplified voice-currents thus thrown upon the metallic circuit will not interfere with the amplifying-apparatus magnet *m*, for the reason that the two coils thereof are connected to oppose each other for metallic-circuit cur-

rents, and any tendency to leakage through the bridge H will be opposed by the high resistance of said coils. A portion of the reinforced current will return backward over the lines L L^2 from the points 15 and 16 of bridge *f* and will circulate through the transmitting-station receiver R or R^2, as the case may be. Leakage by way of the transmitting-secondaries at the terminal stations and through the earth branches *r* and r^2 is, however, reduced to a minimum by the impedance in the one case of said secondaries in series and by the impedance of the coils *h j* and the influence of the central ground connection in the other. So, also, a portion of the talking-current transmitted through the grounded circuit D for the operation of the magnet *m* will be conducted past the intermediate station and will find return through the terminal earth of the distant terminal station; but the advantages secured by the employment of my system for reinforcing the telephone-currents are found to overbalance any operative loss attributable to the derivations to which I have adverted, and by the said system, which divides the gross length of the transmission-line into transmitting and receiving portions, the former of which has its resistance greatly reduced and which enables the transmitting-section of the line with its current thus maintained at great strength to repeat into the receiving-section at the middle part of the said complete transmission-line, the volume of speech reproduction secured is superior to that obtained ordinarily over transmission-lines of similar length under ordinary conditions.

The modification shown in Fig. 2 dispenses with the earth branches at the intermediate station C, and the coils 10 12 of the actuating-magnet *m* are connected directly in the circuits of the main conductors L and L^2, respectively. As in the former case, however, the said coils are wound or connected to cooperate in the earth-completed circuit D and opposingly in the metallic circuit M and are wound upon a single core. They are thus responsive to the currents of the former circuit and irresponsive to those of the latter. In this instance the condensers k^2 k^3, which are provided to prevent the access of leakage or other trespassing steady currents to the magnet *m*, may, as shown, be also placed directly in the main conductors L and L^2.

Having thus fully described my invention and its operation, the following features and combinations are claimed:

1. A reciprocal current amplifying and reinforcing system for telephone-currents in long circuits, consisting in metallic and grounded main circuits formed of the same conductors extending between distant terminal stations through an intermediate station; a transmitter associated with the grounded circuit and a receiver associated with the metallic circuit, at each terminal station; and a reciprocal repeating apparatus at said intermediate station comprising an actuating-magnet associated with said grounded circuit, and a transmitter associated with said metallic circuit and actuated by said magnet, the said apparatus being responsive to the transmitter in the said grounded circuit at either terminal station and adapted to receive the voice-currents developed thereby, and to repeat them into or retransmit them over the said metallic circuit in a reinforced condition, for the operation of the receiver in the said metallic circuit at the other terminal station; substantially as set forth.

2. In a telephone current amplifying or reinforcing system, the combination of a metallic or double conductor circuit extending between two terminal stations and fitted at said stations with earth-terminal attachments to constitute a second and grounded circuit; a receiver and a transmitter at each terminal station connected in said metallic and grounded circuits respectively; and a repeating apparatus at an intermediate point or station consisting of a transmitter in a local circuit together with a battery, a repeating or actuating magnet for said transmitter associated with said main conductors, and wound or connected to be neutral to the currents of said metallic circuit and responsive to the currents of said grounded circuit, and an induction-coil for said transmitter having its primary winding included in said local circuit, and its secondary winding in a bridge of the metallic circuit; substantially as described.

3. A current amplifying or reinforcing telephone system or apparatus, comprising a main line extending as a grounded circuit from one terminal station to an intermediate station or point, and continuing as a metallic circuit from said intermediate station to the other terminal station; a transmitter connected with said grounded circuit at the first-named terminal station; a receiver in said metallic circuit at the other terminal station; and a transmitter in a local circuit, a repeating actuating electromagnet for said transmitter in said grounded circuit, and an induction-coil for said transmitter having its primary winding in said local circuit and its secondary winding in a bridge of said metallic circuit, all at the said intermediate station; substantially as set forth.

4. In a system of telephony, the combination with two main conductors united and provided with earth connections at their ends and thereby formed into independent metallic and earth-completed circuits extending between transmitting and receiving stations; a transmitter at said transmitting-station; an induction-coil therefor having two secondary windings in said main conductors respectively, one on each side of said earth connection, wound

or connected to impress identical voice-currents upon the said conductors in parallel; an impedance-coil at the receiving-station between each main conductor and the common earth connection; and a receiving-telephone bridged at said receiving-station between said main conductors at points outside of said impedance; of a current-amplifying apparatus associated with said main conductors at an intermediate station and comprising a transmitter in a local circuit with a local battery, an earth branch from each main conductor, an actuating or repeating electromagnet for said transmitter having two exciting-coils included in the said earth branches respectively, and an induction-coil for said transmitter having its primary winding in said local circuit and its secondary winding in a bridge of the said metallic main circuit; substantially as and for the purpose set forth.

5. A reciprocally-operating current-amplifying system of long-distance telephony comprising two main conductors united at their ends to constitute in series a metallic circuit between stations and provided at said ends with earth connections to constitute in parallel the joint line conductor of an independent earth-completed circuit between said stations; a transmitter at each of said stations; an induction-coil associated at each such station with the transmitter thereof, and having a secondary winding centrally divided and included in said metallic circuit with one-half on each side of the terminal earth connection, the said half-windings being wound or connected to impress the voice-currents developed by said transmitters upon the said main conductors of said earth-circuit in parallel, and to present maximum impedance to currents flowing in the metallic circuit; a receiving-telephone at each of said stations in the said metallic circuit or in a bridge between the conductors thereof outside of the said induction-coil windings; an electromagnet at a point intermediate of said stations responsive to the voice-currents of said earth-completed main circuit, and having two exciting-coils in earth branches from the parallel constituent conductors respectively thereof, the said coils being connected to coöperate in said earth-circuit but to oppose one another in the said metallic main circuit; a current-reinforcing transmitter in a local circuit together with a battery actuated and controlled by said electromagnet; and an induction-coil having its primary winding in the local circuit of said transmitter and its secondary winding in a bridge between the two main-circuit conductors; whereby the voice-currents developed by the transmitter of either station may be amplified or reinforced at an intermediate point and enabled to act without loss upon the receiver of the other station; substantially as described.

6. In a telephone system, the combination of two main conductors united at their ends to constitute in series a metallic main circuit between distant terminal stations, and provided at said ends with earth connections to constitute in parallel the joint line conductor of an independent earth-completed main circuit between said stations; an induction-coil at each of said stations having two secondary windings connected in the said main conductors respectively, one on each side of the said earth connections, the said windings being thereby connected in series in said metallic circuit and adapted to present maximum impedance to the currents thereof; a transmitter at each such station adapted to develop voice-currents in the said induction-coil windings and thereby in said grounded circuit; a receiving-telephone at each of said terminal stations, and a condenser in series therewith, in a bridge of the said metallic circuit shunting the said induction-coil windings; with a repeating apparatus at an intermediate point of said main circuits, comprising an actuating-magnet having exciting-coils in earth branches of the parallel constituent conductors respectively of said earth-completed circuit, the said coils being wound or connected coöperatively in respect to currents of said earth-circuit and oppositely in respect to currents of said metallic circuit, a condenser in the earth connection of said coils, an induction-coil having its secondary winding in a bridge of said metallic main circuit, and a transmitter controlled by said magnet in response to voice-currents in said earth-completed circuit and reproducing corresponding currents in said main metallic circuit through the medium of said induction-coil; and independent earth branches from the said main conductors respectively also at said intermediate point, in parallel to the said earth branches of said actuating-magnet, and containing respectively low-resistance coils of high inductance; substantially as and for the purposes specified.

7. In a telephone current amplifying or reinforcing system, the combination of a metallic circuit extending between two terminal stations and fitted at said stations with earth-terminal attachments; a receiver and a transmitter at each terminal station connected to operate in said metallic and grounded circuits respectively; a repeating apparatus at an intermediate station operatively associated with the main metallic circuit; an earth-terminal; and a bridge in the main metallic circuit.

8. A current amplifying or reinforcing telephone system or apparatus, comprising a main line extending as a grounded circuit from one terminal station to an intermediate station or point, and continuing as a metallic circuit from said intermediate station to the other terminal station; a transmitter connected with said grounded circuit at the first terminal station;

a receiver in said metallic circuit at the other terminal station; a repeating apparatus at an intermediate station operatively associated with the metallic circuit; an earth-terminal; and a bridge in the metallic circuit.

In testimony whereof I have signed my name to this specification, in the presence of two subscribing witnesses, this 18th day of August, 1903.

JOSEPH J. O'CONNELL.

Witnesses:
CHARLES S. HOLL,
IVOR JEFFREYS.