No. 756,437. PATENTED APR. 5, 1904.

J. TROWBRIDGE.

TELEPHONE.

APPLICATION FILED MAY 18, 1903.

NO MODEL. 2 SHEETS—SHEET 1.

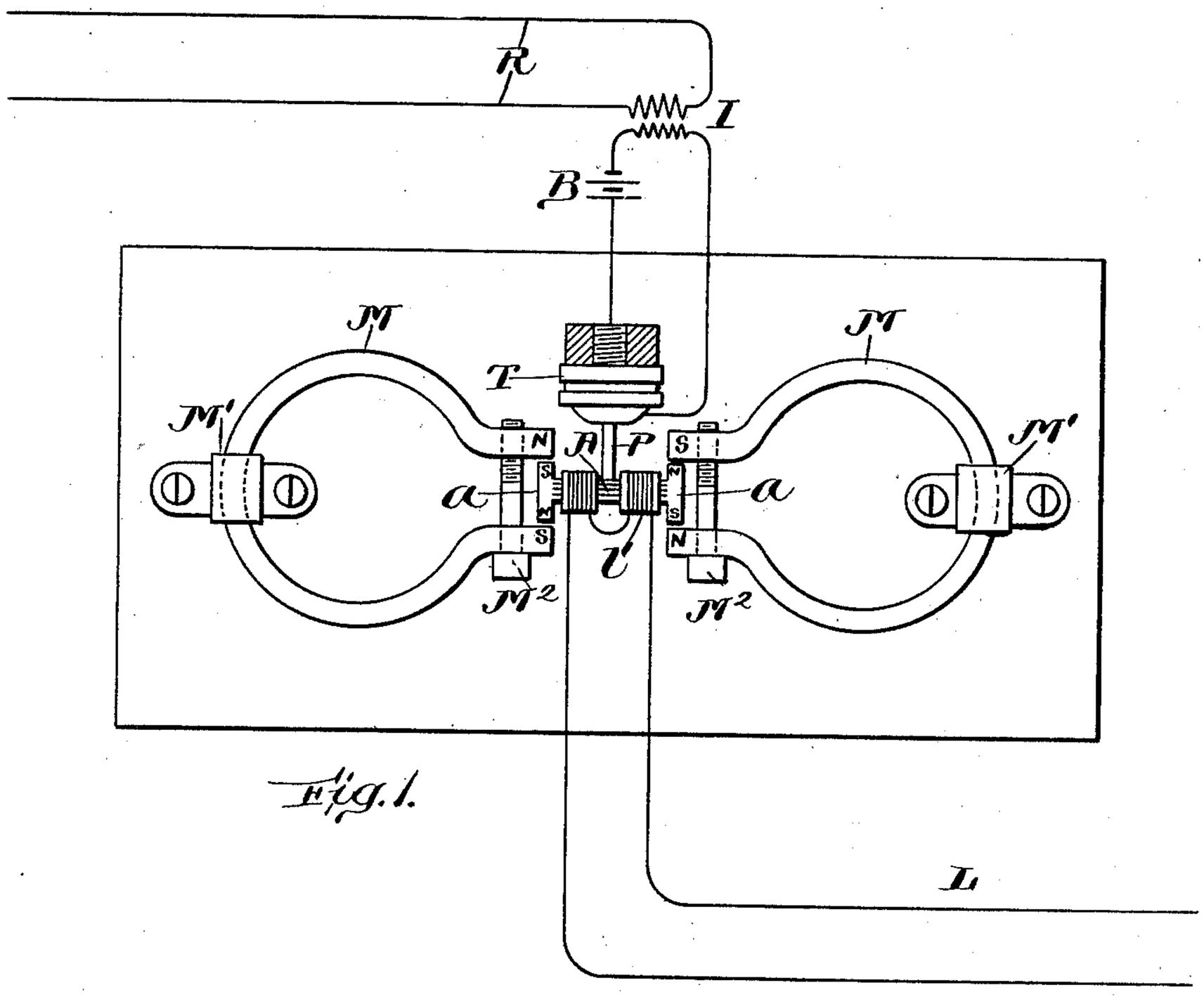

Fig. 1.

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NO MODEL. 2 SHEETS—SHEET 2.

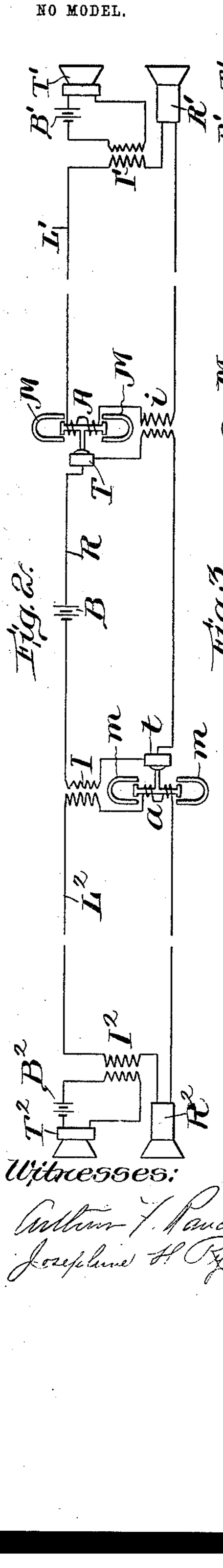

Fig. 2.

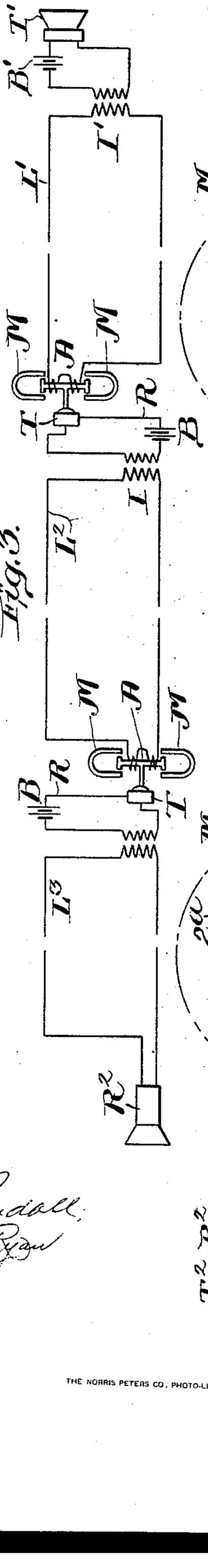

Fig. 3.

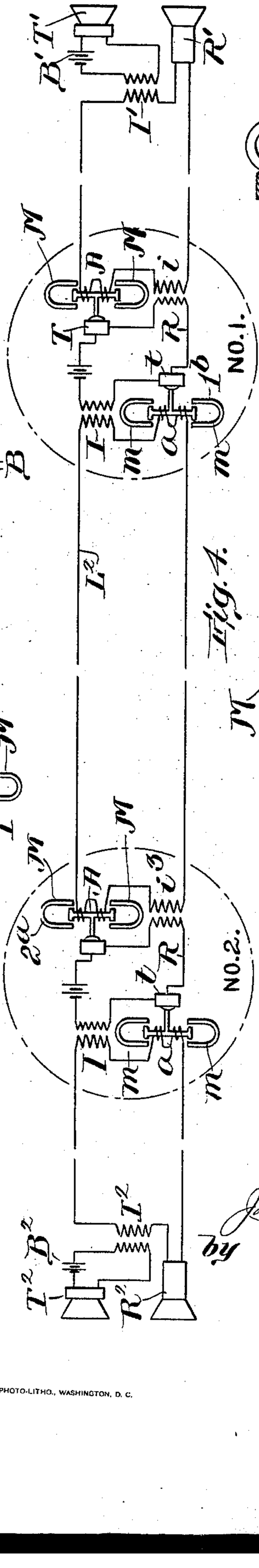

Fig. 4.

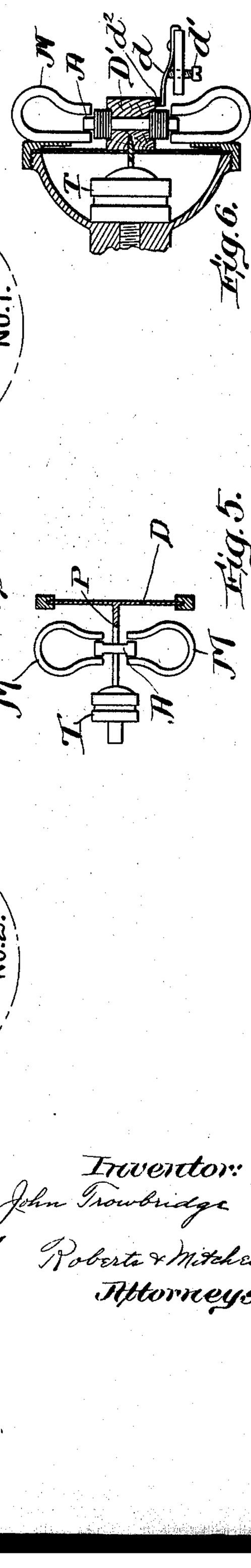

Fig. 6.

Fig. 5.

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No. 756,437. Patented April 5, 1904.

UNITED STATES PATENT OFFICE.

JOHN TROWBRIDGE, OF CAMBRIDGE, MASSACHUSETTS.

TELEPHONE.

SPECIFICATION forming part of Letters Patent No. 756,437, dated April 5, 1904.

Application filed May 18, 1903. Serial No. 157,561. (No model.)

To all whom it may concern:

Be it known that I, JOHN TROWBRIDGE, a citizen of the United States, and a resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Telephones, of which the following is a specification.

The object of my invention is to relay or repeat telephonic current undulations in such manner that relatively feeble undulations in one telephone line will be reproduced in another line with enhanced force and amplitude and without impairment of the essential telephonic character of the current undulations and consequent deterioration of articulation and to provide such a relay apparatus that the telephonic system as a whole, including relays, will reciprocate—that is to say, will transmit speech-messages electrically in either direction, as in the case of the ordinary continuous line.

In United States Letters Patent to Samuel Sheldon and myself, No. 407,799, dated July 30, 1889, there is described a device whereof the purpose was to utilize powerful electrodynamic currents to energize magnets in a relay apparatus. This apparatus was also intended for use as a receiving instrument. As the continuous current generated by a dynamo involves the employment of a commutator, there is set up in the current a rapidly-recurring series of pulsations or throbs due to the action of the commutator, and, as was pointed out in the said Patent No. 407,799, the inductive pulsations produced by the commutator wherever an armature-coil is employed which intersects the lines of force of the surrounding magnetic field (such as illustrated by Siemens's Patent No. 149,797, dated April 14, 1874) will, if the armature be employed as part of a telephonic system, overpower the more delicate undulations characteristic of a telephonic current. Consequently, as the specification of the Trowbridge and Sheldon Patent No. 407,799 sets forth in detail, the object was to arrange an armature wound and suspended in the field of a dynamo-current-excited electromagnet in such manner as to elude the disturbing commutator influences, and thus be capable of transmitting speech as a relay or as a receiver. Unfortunately for the practical accomplishment of this purpose, the hypothesis of the said Patent No. 407,799 failed to take account of other factors, both electromagnetic and mechanical, and consequently the apparatus as a whole, although it obviated the difficulties due to commutator disturbances, failed satisfactorily to transmit the electrical undulations characteristic of and essential to the production of articulate-speech sounds. The net failure of the said apparatus may be correctly characterized thus: The instrument of Patent No. 407,799, whether used as a relay or as a receiver, was incapable of transmitting through its several transforming members, unimpaired and constant in character, the telephonic undulations of the incoming line. The undulations emitted by the instrument were more or less confused with disturbing undulations superposed upon the correctly-modulated incoming waves or pulsations, so that when finally transformed into sound-waves they lost, in whole or in part, the essential quality of articulate speech. This imperfection was usually manifested by confused buzzing or rattling sounds, which always interfered with and often destroyed the pure essential articulate-speech sounds. The Patent No. 407,799, however, set forth a mode of enhancing or amplifying the feeble undulations of a nearly-exhausted telephonic current by converting the undulations thereof into magnetic undulations within a supplemental magnetic field, although, as I have pointed out and as experience proved, the mode of accomplishing this result shown in the said patent failed to take account of many then unsuspected conditions, and thus failed to produce the useful result of transmitting and forwarding with unimpaired articulation the undulations of the incoming current.

I have discovered the electrical and mechanical causes of the defects of the instruments described in Patent No. 407,799 and have by my present invention herein set forth provided an apparatus which by the aid of a symmetrical or balanced magnetic field amplifies the feeble undulations of a nearly-exhausted telephone-line and repeats or transmits them unimpaired in articulate quality to

a second line, thus preserving the exact undulatory correspondence with the sound-waves of articulate speech.

My invention consists of a novel method of repeating electrical undulations and also of an apparatus which employs my new method to transmit and repeat telephonic messages. In an application for United States Letters Patent, Serial No. 157,560, filed concurrently herewith I have set forth and claimed my said method, and I therefore wish it to be understood that while this specification for the purpose of explanation involves a description of my method I reserve the same in whole and part for claim in the said concurrent application.

In the drawings hereto annexed, Figure 1 is a plan view, partly diagrammatic and conventional, of a telephonic repeating instrument or relay embodying my invention. Fig. 2 is a diagram of a complete telephone-line with a single reciprocating relay-station. Fig. 3 is a diagram of a non-reciprocating telephone-line with two relays arranged tandem. Fig. 4 is a diagram of a reciprocating tandem relay-line, and Figs. 5 and 6 show other forms of repeating instruments or relays.

Referring to Fig. 1, upon a suitable base and by means of brackets M′ M′ are mounted a pair of horseshoe-magnets M M. These may be permanent magnets or electromagnets. In the latter case they should be energized by a continuous and steady current, as from a primary or storage battery. Likewise mounted on the base is a telephonic transmitter T, which is here shown as a "solid-back" carbon-button transmitter. Firmly and rigidly mounted on the impulse-receiving member of the transmitter T, as by a stem P, there is an armature A, which is preferably composed of soft-iron rods or short wires. At the ends of the armature A are secured transverse pole-pieces *a a*, likewise of soft iron. I have found by experiment that these pole-pieces while not essential to the performance of my invention nevertheless increase the responsive delicacy of the instrument. The magnets M M are arranged with their north and south poles N S mutually opposite each other, or, in other words, the north poles of the magnets M M are diagonally opposite, as also are the south poles. The resulting induced polarity of the armature pole-pieces *a a* is as shown in Fig. 1 by the letters *n s*. Adjusting-screws M^2 enable the operator to adjust the magnet-poles N S as close as desired to the armature pole-pieces. These screws should be of brass or other diamagnetic material. The magnets M M should be of equal strength, so as to maintain substantial equilibrium in the field and with respect to the armature A.

The mode of mounting the magnets M M in polar opposition, as shown, establishes a field which may be described as quadrilateral and symmetrical or balanced, and the armature A is normally in a state of equilibrium, the balanced forces of the magnetic field exerting no stress upon the impulse-receiving member of the transmitter T. This condition I regard as important, because the transmitter T, whatever be its specific character, is thus maintained in precisely the same delicately-responsive state that characterizes a transmitter which is prepared in the usual and proper way for the reception of sound-waves. I have found by careful experiment that with an armature in an unbalanced non-symmetrical magnetic field connected directly to a transmitter—say to a diaphragm—the constant pull of the magnetic field causes a distortion of the diaphragm, and consequently produces disturbing effects which obscure the proper articulation of the instrument.

The incoming telephonic line L we will suppose to be at such a distance from the transmitting devies at its remote end that the electrical undulations are feeble, so that reproduction of audible speech thereby in the usual manner is impracticable. In circuit with the line L, I wind an armature-coil *l′* on the armature A, preferably bunching the coil in two parts near the ends of the armature, leaving the middle portion thereof bare of coil, and thus obtaining practically all the electromagnetic effect of the coils *l′* while saving weight.

The transmitter T is wired in the usual manner, a battery B of proper strength in its immediate circuit. In this circuit is also located the primary of an induction-coil I, whereof the secondary is in the outgoing or relay line R.

When the incoming line L is quiet and no electrical undulations are passing on it, the relay instrument is in equilibrium; but when electrical undulations are set up in this line the polarity of the armature A is varied in exact correspondence and consonance with the electrical undulations in the line L, and an undulating or vibrating magnetic field is generated in the field of the magnets M. The resulting effect is the product of the armature-coil effects and the balanced-field effect, and the magnetic, and consequently the mechanical, results are enhanced and amplified. Within quite generous limits the strength of the balanced magnetic field may be raised and the consequent product effects increased. Moreover, by means of the polar relationship of the field and armature coil all torsional moments are in equilibrium and the resultant mechanical vibrations are in a straight line and are exerted in this straight line perpendicularly to the impulse-receiving member of the transmitter T and perpendicularly to the planes of contact between the resistance-varying members of the transmitter. This same rectilinear transmission of mechanical effects and perpendicular impact may readily be secured whatever be the structural char-

acter of the transmitter. By preserving these conditions the relay or repeating instrument sends to the outgoing or relay line R undulations precisely corresponding to the incoming undulations of the line L, which excite the armature-coil *l'* and bring into action the vibration-amplifying forces of the balanced field of the magnets M. Thus the transmitter T is impressed with amplified undulating impulses, which are essentially the same in articulate character as the sound-waves which excited the sending instrument at the remote end of the line L, and consequently transmits to the line R unimpaired in articulate quality amplified undistorted undulations essential to the production of intelligible articulate speech, which may then be made manifest by a proper telephonic receiver at the remote end of the line R.

The relay or amplifying effect sensible at the receiver end of the line R is due to several conditions—first, the product magnetic amplifications of the armature-coil undulations by means of the balanced magnetic field, whereby the mechanical impress upon the transmitter T is emphasized; second, to the relay-battery B, which supplies fresh electrical energy for transmission of undulations along the line R, and, third, to the preservation and transmission, unimpaired and unobscured and undistorted by extraneous influences, of the undulatory articulations of the original telephonic current.

In Fig. 2 there is illustrated by diagram an arrangement for obtaining reciprocal relay effects between two distant stations. At one station is located the usual transmitter T', with battery B' and the primary of the induction-coil I' in its circuit. The line L', including the secondary of the induction-coil I', armature-coil at A, the secondary of the induction-coil *i*, and the receiver R', leads to the relay-station. At this relay-station two instruments similar to that shown in Fig. 1 and above described are set up, the instrument M M A T in adjustment to receive and repeat impulses from transmitter T' and the instrument *m m a t* to receive and repeat impuses from transmitter T^2, which is at the end of the line remote from transmitter T'. The two relay instruments at the relay-station are arranged as follows: The same circuit R includes the two transmitters T *t*, the relay-battery B, and the primaries of the induction-coils I and *i*. At the station remote from the instruments T' and R' are located the transmitter T^2, with the battery B^2 and the primary of the induction-coil I^2 in circuit. The line L^2 includes the secondary of the induction-coil I^2, the receiver R^2, armature-coil *a*, and the secondary of induction-coil I. The operation of this system is as follows:

Speech vibrations stimulate current undulations in the primary of coil I' and generate corresponding undulations in the line L'. These electrical undulations are converted into magnetic undulations at the armature-coil A, and these again are supplemented by reciprocal magnetic effects of the balanced field of magnets M M. As above described in connection with Fig. 1, these reinforced magnetic undulations are reconverted into electrical undulations precisely corresponding to the original speech vibrations at the transmitter T', and these undulations in circuit R set up corresponding undulations in the circuit L^2, which are in the usual manner finally reconverted into sound-waves at the receiver R^2, where the speech delivered at transmitter T' is reproduced.

The current undulations of the circuit L' passing through the secondary of the coil *i* produce in its primary no sensible effect. Thus the resistance to the transmission of undulatory effects backward, as we may say, through the relay instrument *m m a t* is practically prohibitory.

When the speech is made at transmitter T^2, the reciprocal effect is perfect. The relay *m m a t* receives, amplifies, and transmits the undulations to the line L' through the induction-coil *i*, and the receiver R' reconverts them into speech. Whatever be the source of undulations, the effective relay instrument takes the message and repeats it, one relay works in one direction and the other in the opposite direction, and each automatically to the exclusion of the other. The practical results, therefore, which appeal to the users of the instruments at the ends of the line are the same as if they were conversing over a simple telephone-line short enough to render the direct communicating undulatory current effective.

The preservation of the exact articulate character of the undulatory current which is peculiar to my method of repeating enables one to use several relays like that shown in Fig. 1 or relay-stations like that shown in Fig. 2 in tandem. I illustrate a simple non-reciprocating tandem relay-line in Fig. 3. Therein the impulses from transmitter T' excites the relay at station 1, thence the undulatory current is passed on amplified to station 2, and thence to receiver R^2.

In Fig. 4 I illustrate an arrangement of complete reciprocating relay-stations in tandem. In this system the arrangement of terminal station T' R' with relation to relay-station 1 and that of terminal station T^2 R^2 with relation to relay-station 2 are the same as the relations of the respective terminal stations of Fig. 2 of the relay system. The secondary of the induction-coil I, the armature-coil of relay instrument 2^a, the secondary of induction-coil i^3, and the armature-coil of relay instrument 1^b are in the line which stretches between relay-stations 1 and 2. I have constructed a system of this character in which the line-resistances were analogous to a line

from New York to Chicago as between terminal T′ R′ and relay-station 1, a line from Chicago to Omaha as between relay-stations 1 and 2, and a line from Omaha to Denver as between relay-station 2 and terminal station T^2 R^2, and have maintained clear, audible, and unimpaired a conversation with an assistant over the said line, which transmitted speech reciprocally as readily as an ordinary short telephone-line.

It will be observed that in contrast with the instrument and mode of operation described in Patent No. 407,799 I have by my present invention produced the following electrical, magnetic, and mechanical conditions: Instead of converting the product effects of an armature and surrounding field into rotary movements by means of unbalanced torsional magnetic product effects characteristic of the said patent I have maintained torsional balance in magnetic effects and produced direct rectilinear mechanical movements. Whereas in the instrument of Patent No. 407,799 the curvilinear mechanical impulses of the suspended armature caused distortions and disturbances in the transmitter, in my present invention no such distortion or disturbances take place. Instead of making contact between the armature-coil and the receiving members of a transmitter by means of initial pressure (itself a cause of mechanical distortion and confusion of articulate with inarticulate electrical undulations) I have secured the armature-coil directly and rigidly to the receiving member of the transmitter, thus avoiding any confusing stresses and also eliminating the effect of individual non-electric vibrations of the independently-suspended armature. In short, I have by my present invention contrived a method and apparatus whereby a symmetrical or balanced magnetic field, as an independent source of power, is enabled in coaction with an exciting-armature to repeat unimpaired the articulate undulations of a telephonic circuit with fresh and amplified transmission impulses in a second or relay circuit, whereas by the apparatus and mode of operation shown in Patent No. 407,799 this functional result could not be obtained. Also I have by my present invention contrived a method and apparatus whereby the symmetrical or balanced magnetic field in connection with an exciting-armature may be employed to directly produce the mechanical vibrations of a receiver-diaphragm, so that the resulting sounds will be clear undistorted articulate speech free from disturbing sounds.

In solid-back microphone-transmitters now in general use the metallic diaphragm D is, as shown in Fig. 5, rigidly clamped at its edges to a casing, on which the electrode-holder is also rigidly fixed. The stem P is fixed rigidly at one end to the middle of the metallic diaphragm and at its opposite end to the middle of the usual mica diaphragm closing the end of the electrode-holder and against which the movable electrode of the microphone bears. This is the usual construction, and in carrying my invention into effect the only change necessary to make in the microphone-transmitter as at present constructed is to mount the small iron armature A on the stem P between the metallic and mica diaphragms and fix the two magnets M within the casing of the transmitter properly disposed with relation to the iron armature A.

In Fig. 6 I have shown another form of instrument, which differs from that above described in that a block D′ of whitewood is fixed to the middle of the metal diaphragm, and in this block D′ the armature A is mounted with only its two ends projecting therefrom. By thus practically burying the armature in the block of wood D independent vibrations of said armature, which might conflict with the vibrations consonant with the electrical undulations, are prevented, the inclosing body of wood tending to smother the same without itself being vibrated.

In telephone systems comprising a plurality of repeating instruments I find that it is desirable to make each adjustable—that is, to provide some means by which the action of each instrument may be regulated so as to work in harmony with the other instruments of the system. To this end I may provide each instrument with a spring-finger *d*, fixed to any suitable support and arranged to press through a block of rubber d^2 upon the side of the block D′. The pressure of the spring-finger *d* may be regulated by means of a screw *d′*, by means of which the action of the instrument may be regulated to accord with the other instruments of the system. The arrangement shown in Fig. 5 has the advantage of supporting the vibrating armature A at both sides, so that the slight bending effect due to the weight of the armature is wholly obviated. Any support at the side away from the transmitter T will serve for this purpose; but I prefer to employ a diaphragm clamped at its periphery for two reasons. First, the diaphragm does not tend to confuse the pure articulate vibrations of the armature by independent tremors of its own, and, moreover, the diaphragm itself used in the manner described produces audible speech, which enables the listening operator to detect any disturbing influences which may be at work, and thus to ascertain if the instrument is working properly to relay the message. A damping device, such as indicated in Fig. 6, may be thus employed to suppress any undesirable vibrations.

With a single relay-station in line the disturbing effects due to local vibration in my relay instruments are so slight as to be negligible; but with a tandem arrangement employing several relay-stations the local dis-

turbances negligible with a single station are liable to accumulate at each relay and should be suppressed.

What I claim is—

1. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a position of balance therein, a telephonic transmitter, and connections arranged with relation to the reciprocal effects of the coil and magnetic field to impart mechanical vibrations perpendicularly to the receiving member of the transmitter.

2. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a position of balance therein, a telephonic transmitter outside the balanced field, and connections arranged with relation to the reciprocal effects of the coil and magnetic field to impart mechanical vibrations perpendicularly to the receiving member of the transmitter.

3. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a position of balance therein, a telephone-transmitter, and connections arranged with relation to the reciprocal effects of the coil and magnetic field to impart mechanical vibrations to the receiving member of the transmitter in a straight line.

4. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a position of balance therein wound so that the mechanical vibrations due to the reciprocal magnetic effects of the coil and field are rectilinear, a telephonic transmitter, and connections to impart thereto the said rectilinear mechanical vibrations.

5. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a neutral location in the field, a telephonic transmitter, and connections arranged with relation to the reciprocal effects of the coil and magnetic field to impart mechanical vibrations perpendicularly to the receiving member of the transmitter.

6. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a neutral location in the field wound so that the mechanical vibrations due to the reciprocal magnetic effects of the coil and field are rectilinear, a telephonic transmitter, and connections to impart thereto the said rectilinear mechanical vibrations.

7. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a position of balance therein, a telephonic transmitter, and a stem rigidly connecting the armature-coil with the receiving member of the transmitter.

8. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a neutral location in the field, a telephonic transmitter and a stem rigidly connecting the armature-coil with the receiving member of the transmitter.

9. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil in a position of balance therein, a transmitter, a stem fixed to the transmitter's receiving member and to the armature-coil, the coil, stem and transmitter arranged with relation to the reciprocal magnetic effects of the coil and field to impart rectilinear mechanical vibrations to the receiving member of the transmitter.

10. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil therein, a telephonic transmitter, a mounting for the armature secured to the transmitter at one side and on a support at the other side.

11. In an instrument for repeating electrical undulations, the combination of a magnetic field, an armature-coil therein, a telephone-transmitter at one side of the armature, a diaphragm at the other, and a mounting for the armature secured at one end to the transmitter and at the other to the diaphragm.

12. In an instrument for repeating electrical undulations, the combination of a pair of horseshoe-magnets arranged with their similar poles in diagonal opposition, an armature-coil in neutral location in the field of the said magnets, a transmitter, connections between the transmitter and armature-coil, the coil wound with relation to the field to impart rectilinear vibrations to the transmitter.

13. In an instrument for repeating electrical undulations, the combination of a pair of horseshoe-magnets arranged with their similar poles in diagonal opposition, an armature-coil in neutral location in the field of the said magnets, a transmitter on one side of the coil and a support on the other, and a stem holding the armature, and connected with the transmitter and the support.

14. In an instrument for repeating electrical undulations, the combination of a pair of horseshoe-magnets arranged with their similar poles in diagonal opposition, an armature-coil in neutral location in the field of the said magnets, a transmitter on one side of the coil and a diaphragm on the other and a stem holding the armature, secured to the transmitter and to the diaphragm.

15. In a telephone system, two telephone-lines, a pair of relay instruments whereof the principal parts are a microphonic transmitter, an armature-coil connected to the transmitter, and a magnetic field surrounding the armature-coil, each of the two telephone-lines branched to include the armature-coil of one relay in one branch and the transmitter of that relay in the other branch inductively.

16. In a telephone system, in combination, a battery-circuit, a battery therein; two induction-coils, each having its primary arranged in said circuit, two transmitters in said circuit, two magnetic fields one for each transmitter; two armature-coils one in each field

and each controlling the transmitter of its respective field; two telephone-circuits each including one of said armature-coils and also the secondary of one of the induction-coils.

17. In a telephone system, in combination, a battery-circuit; a battery therein; two induction-coils each having its primary arranged in said circuit; two transmitters in said circuit; two magnetic fields one for each transmitter; two normally balanced armature-coils one in each field and each of said coils arranged to control one of the transmitters and two telephone-circuits each including one of said armature-coils and also the secondary of one of the induction-coils.

18. In a telephone system in combination, a battery-circuit; a battery therein; two induction-coils each having its primary arranged in said circuit; two transmitters in said circuit; two magnetic fields one for each transmitter; two normally balanced armatures, one in each field each of said armatures being provided with an armature-coil and arranged to control one of the transmitters, and two telephone-circuits each including one of said armature-coils and also the secondary of one of the induction-coils.

Signed by me, at Boston, Suffolk county, Massachusetts, this 5th day of May, 1903.

JOHN TROWBRIDGE.

Witnesses:
ODIN ROBERTS,
ARTHUR F. RANDALL.