F. H. FAY, T. SHAW & J. J. PILLIOD.
PHANTOM CIRCUIT.
APPLICATION FILED OCT. 7, 1914.

1,173,655. Patented Feb. 29, 1916.

3 SHEETS—SHEET 1.

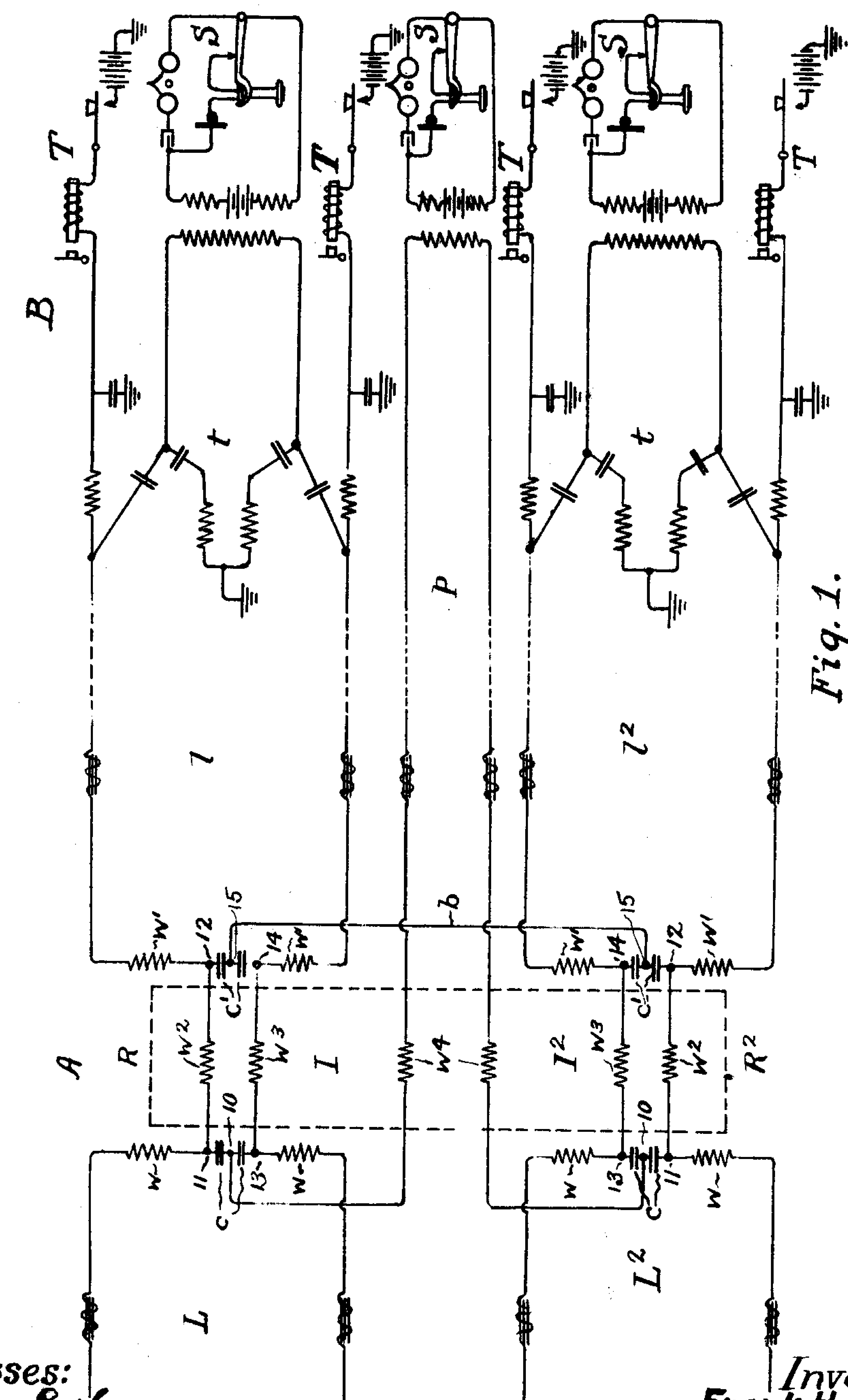

Fig. 1.

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By Thomas D. Lockwood Atty.

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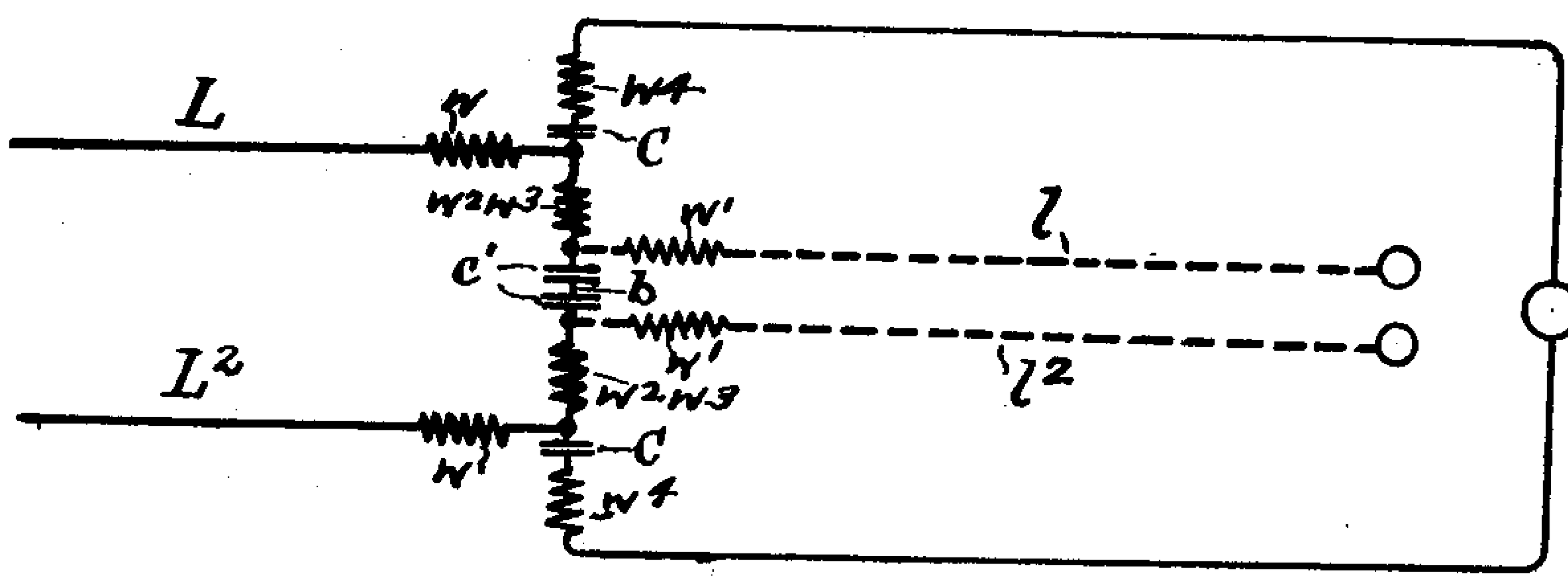
3 SHEETS—SHEET 2.

Fig. 2.



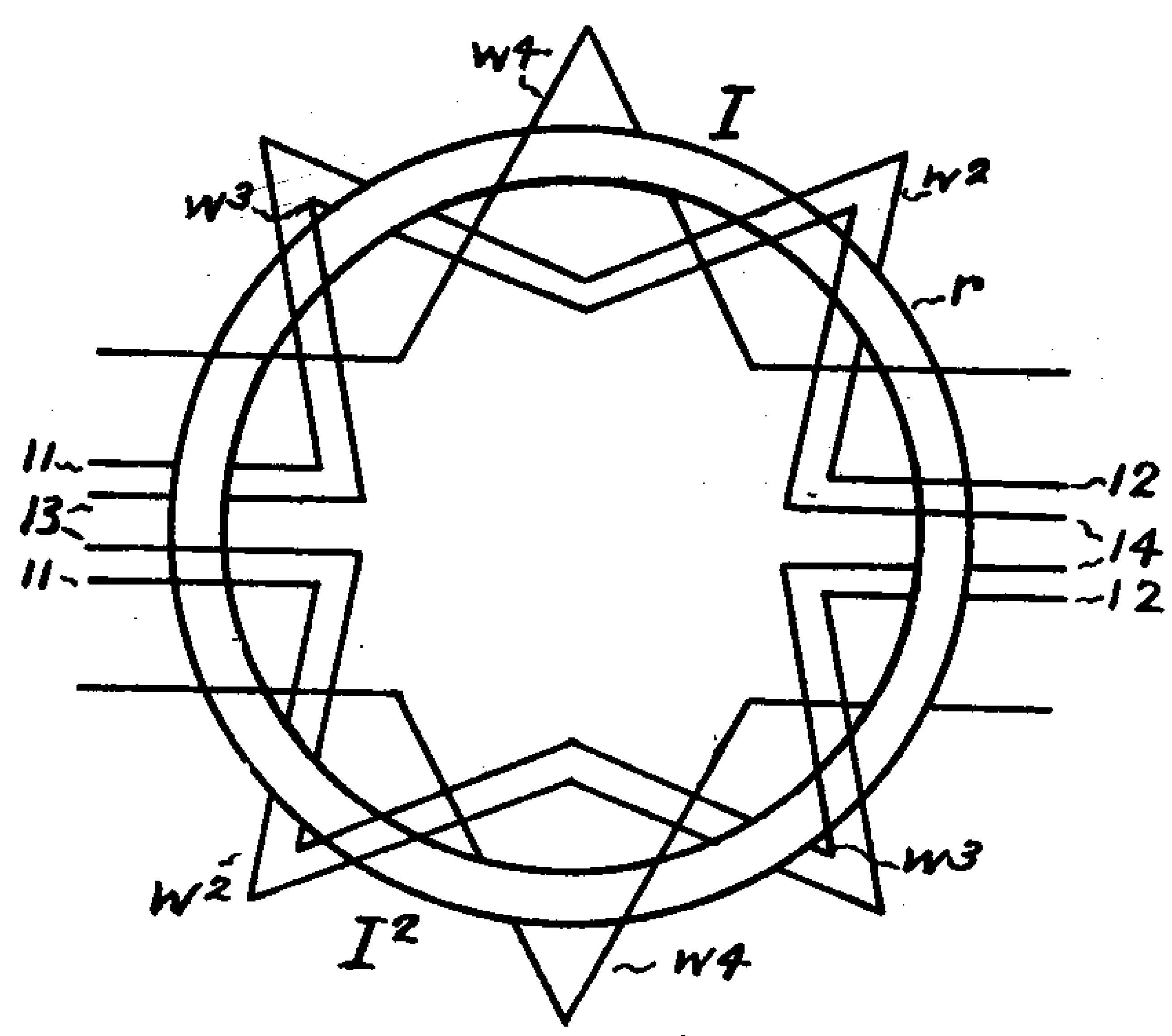


Fig. 3.

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3 SHEETS—SHEET 3.

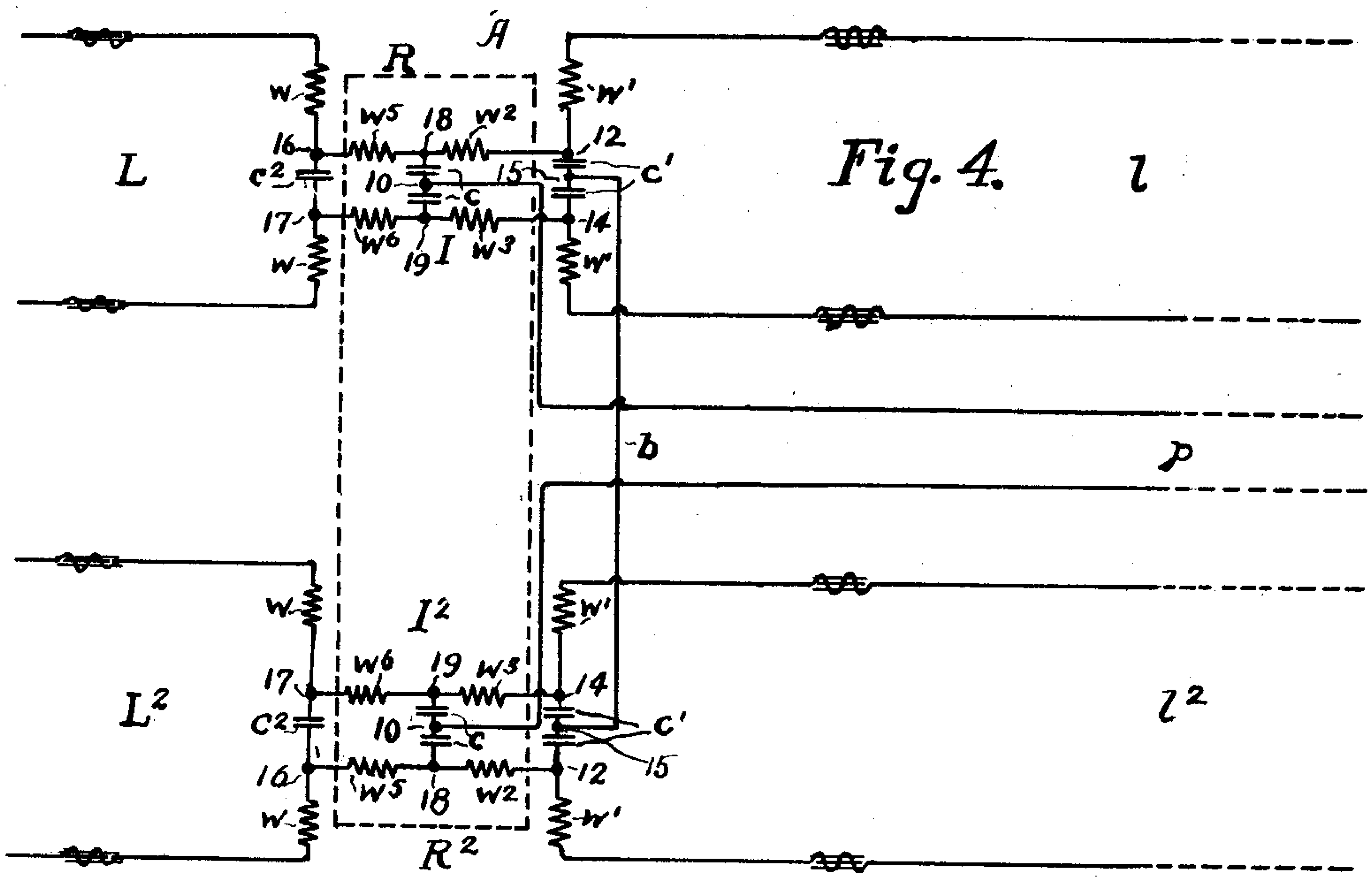

Fig. 4.

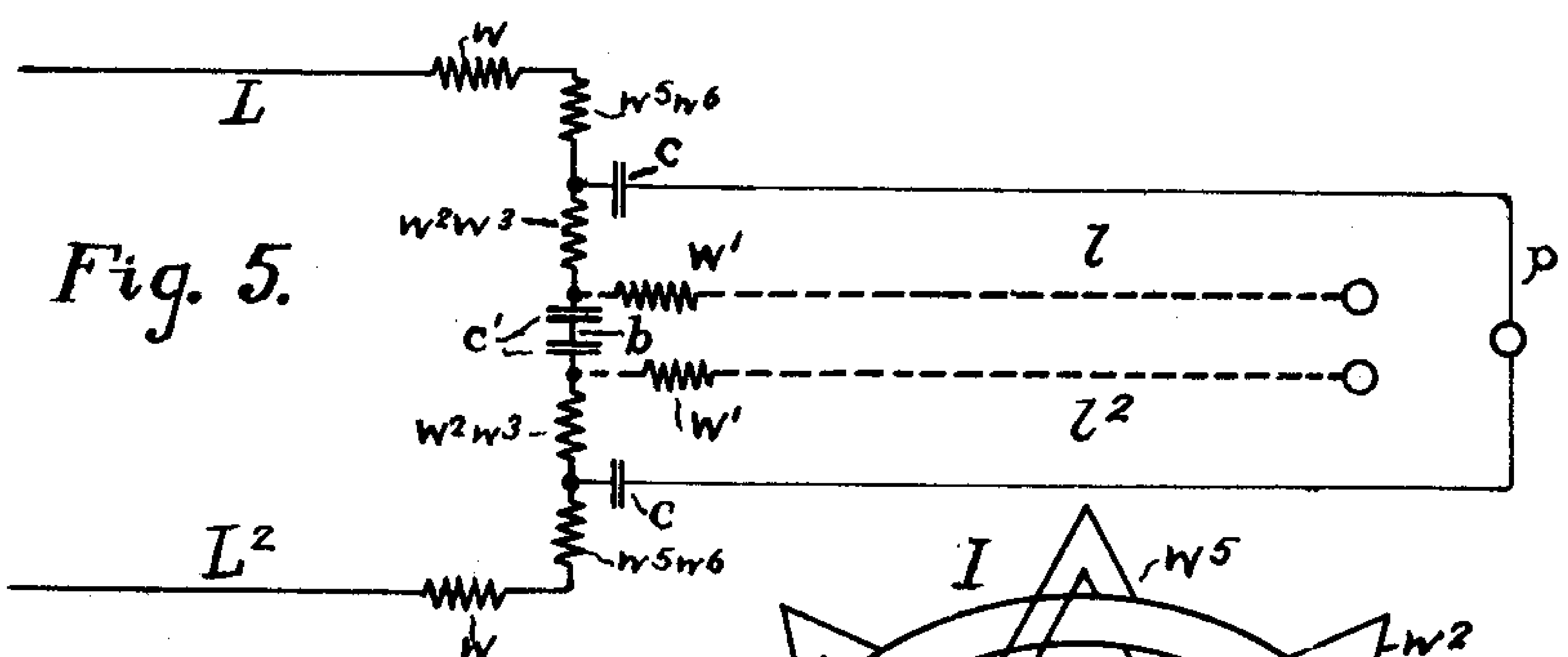

Fig. 5.

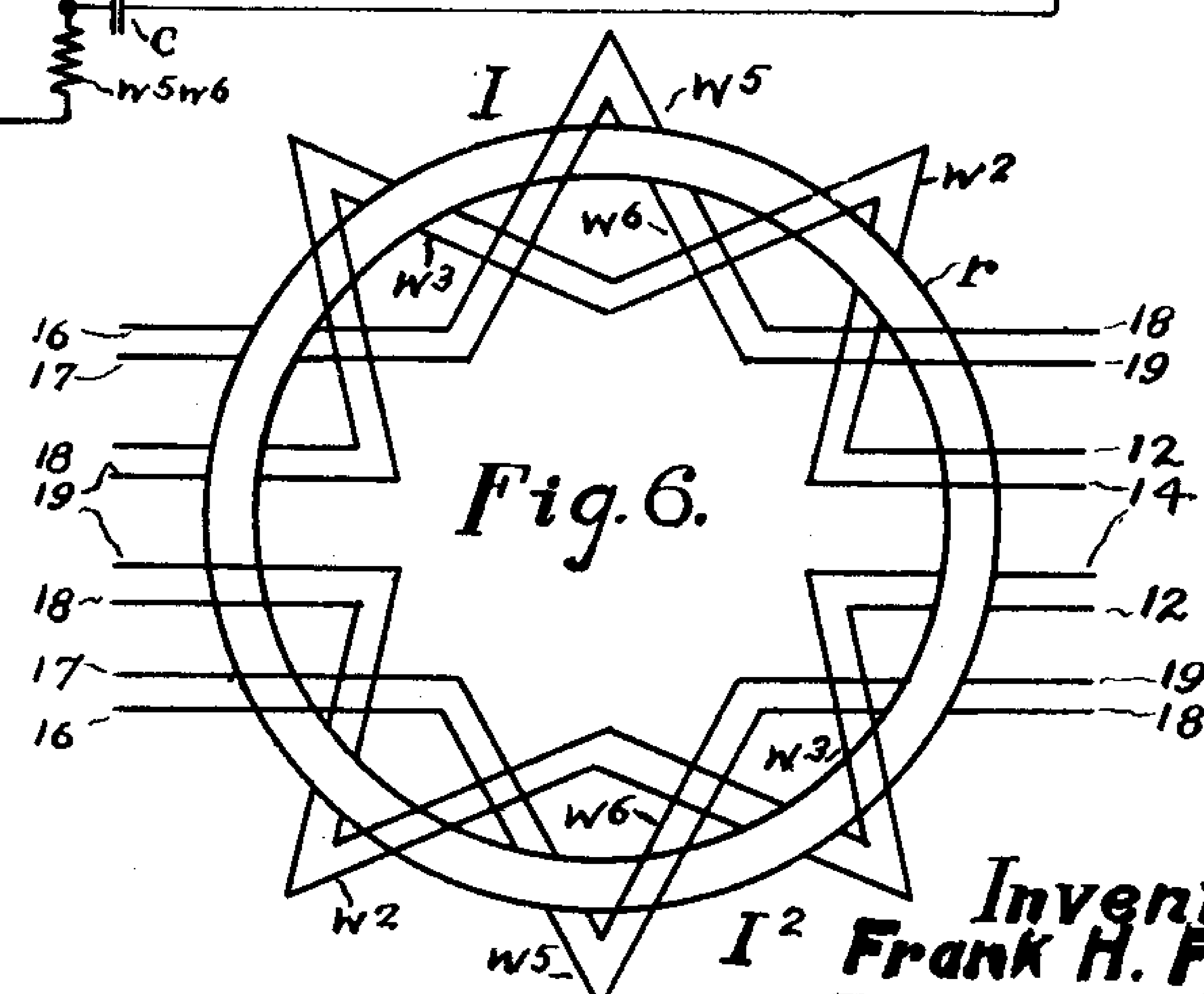

Fig. 6.

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UNITED STATES PATENT OFFICE.

FRANK H. FAY, OF BROOKLYN, NEW YORK, THOMAS SHAW, OF HACKENSACK, NEW JERSEY, AND JAMES J. PILLIOD, OF CHICAGO, ILLINOIS, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

PHANTOM CIRCUIT.

1,173,655. Specification of Letters Patent. Patented Feb. 29, 1916.

Application filed October 7, 1914. Serial No. 865,442.

To all whom it may concern:

Be it known that we, FRANK H. FAY, THOMAS SHAW, and JAMES J. PILLIOD, residing at Brooklyn, Hackensack, and Chicago, in the counties of Kings, Bergen, and Cook and States of New York, New Jersey, and Illinois, respectively, have invented certain Improvements in Phantom Circuits, of which the following is a specification.

In telephone practice, in connection with phantom circuits, it may be found desirable to change the type of circuit from one which is properly organized to prevent disturbance to one which tends to introduce noise induction from other circuits and crosstalk between the phantoms. An instance of this is where open wire circuits are led into central stations through non-duplex cable in which the sides or the physical circuits of each phantom are carried by separate pairs, instead of through duplex cable having both pairs of the phantom assembled in a quad. In such cases, it has been customary to install the usual phantom repeating coils at the end of the open wire circuits and bring in the phantoms from that point by means of physical circuits furnished by separate pairs in the cable. By this plan, however, the conductive continuity of the side circuits is interrupted at the repeating coils, and when it is desired to utilize the conductors for telegraph operation the composite sets must be installed at the juncture of the open lines and the cable, and the Morse legs carried to the central station by separate conductors. Even in absence of composite operation arrangements must be made for closing the circuits through to permit testing, and this requires the presence of relays associated with the phantom repeating coils and conductors in the cable to control said relays. This places apparatus where it is more troublesome to maintain, and requires the presence of added conductors in the cable. This invention overcomes these difficulties by furnishing direct current paths through the repeating coils or other phantom-forming devices, the elements being so arranged that phantom circuit unbalance and phantom to phantom crosstalk in the non-duplex cable is prevented. At the same time, the means for effecting these ends may be so organized as to reduce reflection losses in the phantom circuit, if the phantom proper and its physical extension are of different impedance.

In the accompanying drawings, in which like reference characters are applied to similar parts throughout, Figure 1 illustrates the invention diagrammatically in its application to the sections of a phantom circuit in which the impedance is to be stepped up; Fig. 2 shows the theory of this organization by a simplified diagram; Fig. 3 is a diagrammatic representation of an autotransformer employed in the system of Figs. 1 and 2; and Figs. 4, 5 and 6 correspond to Figs. 1, 2 and 3, respectively, illustrating an arrangement for producing a stepping down of the phantom impedance.

In Fig. 1 of the drawings appear telephone lines L and L^2, which may be of open wire and loaded, they being continued from the point A, say at the outskirts of a city, to a central station B by non-duplex cable extensions l and l^2, also loaded. To each line may be connected telephone apparatus S. Composite sets t provide for telegraph transmission over each of the conductors of the open wire line and its cable extension, the customary telegraph apparatus being contained in the Morse legs T of the circuits. To allow the formation of the phantom, devices are located at the junction A between each of the lines L, L^2 and their extensions l, l^2, these devices in the present instance consisting of the well known phantom repeating coils R and R^2, having line windings w, w and extension or drop windings w', w'. These operate as usual to inductively convey from one section to the other voice currents flowing through the conductors of the side circuits in series, and to furnish points 10 between the windings w, w, neutral with respect to such side current, to which the physical extension p of the phantom may be joined to conduct voice currents passing through each of the pairs of conductors of the lines L and L^2 in parallel. To the extension p may be connected telephone apparatus S. In this instance the impedance of the extension p is assumed to be greater than that of the open wire phantom, as would be the case if the phantom extension were loaded to approximate the impedance of the side circuits L and L^2.

Since the phantom repeating coils open the sections of the conductors L, L^2 and l, l^2

to direct current, means are provided for conductively associating each of these, such means being preferably furnished by windings of autotransformers I, I^2 which also serve to step up the impedance of the phantom to that of its extension. To enable these devices to perform their plural functions, the windings of each are included in the circuits in a manner which may be more clearly understood by considering the simplified diagram of Fig. 2 in connection with Fig. 1.

In Fig. 2 light lines represent single conductors, while those corresponding to two conductors in parallel are heavy. Windings w^2, w^3, of each autotransformer, which, for reasons which will later more clearly appear, are termed bridge windings, unite points 11, 12 and 13, 14, respectively, at the inner extremities of the windings w and w' of the phantom repeating coils R, R^2. These furnish independent paths for telegraph or other direct currents in each of the conductors of the side circuits and their extensions. Bridged across the points 11 and 13 are balanced condensers c, c, between which the connections 10 for the conductors of the phantom extension p are made. In each of said phantom extension conductors is a series winding w^4 of the autotransformer. In a bridge between the points 12 and 14 at the inner ends of the drop windings w', w', of each phantom repeating coil is another pair of balanced condensers c', c', and at neutral points 15 at the center of each is joined a conductor b completing a short-circuiting bridge. Referring particularly to Fig. 2, it will be seen that the windings w^2 and w^3 of the autotransformers I and I^2, with the condensers c' and the connection b, are in a bridge of the phantom at the juncture of the low and high impedance sections, while the windings w^4 are in series with the physical extension of the phantom. The reflection reducing effect of the transformers equals the ratio of the impedance of the series windings w^4 inductively associated with the bridge windings w^2, w^3 in parallel-series-aiding to the impedance of said bridge windings in parallel-series-aiding. Obviously, this relation may be varied to meet the particular conditions encountered. The autotransformers cause transmission losses in the phantom circuit proportionate to their self and mutual impedances; these may be made small. With respect to the side circuits, the bridge windings w^2, w^3 are in series-opposing, and as they are included in said side circuits close to neutral points, practically none of the current in these circuits flows through them and the transmission losses are slight. Since the series windings w^4 are entirely removed from side circuits they have no effect thereon.

Naturally a conductive connection between the lines L, L^2, which carry phantom current and the side circuit extensions l, l^2 makes possible an unbalance of the phantom and noise induction, if one of these side circuit extensions be switched to a line having greater admittance to ground than the line to which the other side circuit extension may be united, because more phantom current will pass to ground through one of the connected lines than through the other. But with this invention the terminal conditions of the side circuit extensions are practically without influence on the phantom, because of the conductive association of the side circuit extensions with the phantom at substantially neutral points 12 and 14 therein, located in a bridge consisting of autotransformer windings w^2, w^3, condensers c' and the conductor b, the impedances of the condensers being low in comparison with that of the windings in parallel-series-aiding. This circuit arrangement reduces to a negligible minimum any induced potentials to ground acting on the diverse admittances to ground of the side circuit terminal extensions. The conductive relations between the phantom lines and the non-duplex side circuit extensions also tend to promote noise induction and crosstalk troubles, because of the fact that the side circuit extensions are not balanced for phantom working. Therefore, such phantoms will normally crosstalk to other phantoms similarly constituted, and will also tend to be affected by noise induction carried through the terminal cable by any other phantom or physical circuit or due to direct exposures of the terminal cable to foreign disturbing systems. With this invention, however, crosstalk troubles of the above character are practically eliminated by substantially excluding the phantom current from the side circuit extensions; and the noise troubles are minimized by preventing noise induction picked up by the side circuit extensions, acting as an unbalanced element of the phantom, from being transferred to the balanced portion of the phantom. These results are accomplished by the peculiar arrangement of the phantom interference-preventing bridge previously referred to, in which the autotransformer bridge windings w^2, w^3, by virtue of their impedance, oppose the transfer of crosstalk and noise currents between the balanced and unbalanced elements of the phantom circuit and vice versa, while simultaneously assisting in the establishment of the conductive through-circuit required for Morse or testing purposes, and the condensers c' in conjunction with the short-circuit b act as a low impedance shunt across the series path of the disturbing currents, which includes the high impedance autotransformer windings. Conductive interference between the Morse legs is avoided by the presence of the condensers c and c' in the phantom-connecting and short-circuiting bridges, the capacity of these being small enough to prevent cross fire yet sufficiently large to give good telephonic transmission.

In the previous description the devices I and I^2 have been referred to as having distinct functions in connection with the two side circuits, and while they could in fact be independent, for the sake of obtaining more perfect balance their windings are preferably placed upon a common core. Such an arrangement is illustrated in Fig. 3 of the drawings. The windings for each side circuit are placed on opposite halves of the usual toroidal core *r*. The bridge windings w^2, w^3 are preferably in the form of a twisted pair extending uniformly about each half core. This gives the best balance and is convenient in manufacture, while the increased capacity effect between the conductors is not objectionable, on account of their practical freedom from side circuit current. The series winding w^4 is carried outside the corresponding bridge windings about the half core. Considered with regard to the phantom current the windings of the autotransformers I and I^2 are distributed evenly about the entire core, preventing leakage losses. Such a coil for stepping up the impedance of the line phantom to that of the phantom extension in the ratio of 1400 to 1800 might have the following windings: Each bridge winding w^2 or w^3 in either coil I or I^2 has 1392 turns of No. 26 B. and S. gage single cotton-covered copper wire, having a direct current resistance of 44.1 ohms and impedance values together in series-parallel-aiding to phantom current of 800 periods per second of 5400 ohms resistance and 7 henries inductance; each series winding w^4, 187 turns No. 16 B. and S. gage single cotton-covered copper wire, direct current resistance 0.7 of an ohm, impedance together in series-aiding 99 ohms and 0.13 of a henry. The mutual impedance between the bridge and series groups would be 730 ohms and 0.95 of a henry. The condensers *c* and *c′* of this system would have capacities of about two microfarads each.

Sometimes the phantom circuit extension may be of lower impedance than the line portion, as in the case of terminating a loaded open wire phantom in a non-loaded physical cable circuit. Here it is necessary to so locate the series windings that their impedance is applied to the line portion of the phantom; that is, that they are in direct conductive relation with the line wires of the circuits. Such an arrangement appears in Figs. 4 and 5 of the drawings. The circuits L, *l*, L^2, l^2 and *p* and the phantom repeating coils R and R^2 are as before. So too are the bridge windings w^2 and w^3 of the autotransformers I and I^2 and the short-circuiting bridge *c′ b c′*, but there is a series winding w^5 or w^6 for each of the side circuit conductors from points 16 and 17 at the inner ends of the line windings of the phantom repeating coils to points 18, 19, respectively, at the inner extremities of the bridge windings w^2, w^3. The condenser bridges providing the neutral connections 10, 10 for the phantom extension *p* are taken from the last named points 18 and 19. The reflection-reducing efficiency of this arrangement will be measured by the impedance ratio of the parallel-series-aiding grouping of the series windings w^5, w^6 inductively associated with the parallel-series-aiding grouping of the bridge winding to the impedance of the parallel-series-aiding grouping of the bridge windings w^2, w^3. The paths for the conduction of direct current are through the series and bridge windings w^5, w^2 and w^6, w^3 in series. The general considerations governing the operation of this system are similar to those of Figs. 1 and 2. A bridge containing a condenser c^2 is preferably placed across each side circuit at the points 16 and 17, to aid in reducing side circuit transmission losses in the series windings of the autotransformers by acting as a short circuit thereon at telephone frequencies. As before, the autotransformer windings are best assembled upon a single core, as illustrated in Fig. 6, with the elements belonging to each side circuit on separate halves. As the pairs of series windings, like the bridge windings, are practically free from side circuit current, they may also conveniently be carried through a twisted pair. For a circuit in which the open wire phantom presents an impedance of 1400 ohms, while the terminal cable has an impedance of 900 ohms, a coil with windings as follows might be employed: Each bridge winding w^2 or w^3, 1117 turns of No. 26 B. & S. gage single cotton-covered copper wire with a direct current resistance of 35 ohms and an impedance value together in series-parallel-aiding of 3535 ohms and 4.5 henries; series windings w^5, w^6, each 280 turns of No. 20 B. & S. gage single cotton-covered copper wire, direct current resistance of 2.5 ohms, impedance together in series-parallel-aiding 222 ohms and 0.28 of a henry. The mutual impedance between the bridge and series groups would be 885 ohms and 1.12 henries. Two microfarad condensers *c* and *c′* might be used, while the condenser c^2 would be one microfarad or less.

Having thus described our invention, we claim:

1. In a telephone circuit comprising side circuits together furnishing a phantom circuit and physical extensions of said side circuits and phantom circuit, a phantom-forming device connecting each side circuit and its extension and from which the phantom extension is led, and reflection-reducing means furnishing direct current paths

through the phantom-forming devices to connect the respective sections of the conductors of the side circuits.

2. In a telephone circuit comprising side circuits together furnishing a phantom circuit and physical extensions of said side circuits and phantom circuit, a phantom-forming device connecting each side circuit and its extension and from which the phantom extension is led, and an autotransformer furnishing direct current paths through the phantom-forming device to connect the respective sections of the conductors of the side circuits.

3. In a telephone circuit comprising side circuits together furnishing a phantom circuit and physical extensions of said side circuits and phantom circuit, a phantom-forming device connecting each side circuit and its extension and from which the phantom extension is led, and an autotransformer having windings in series with the side circuits and the extensions.

4. A phantom circuit comprising side circuits and extensions thereof, phantom-forming devices inductively associating the side circuits and their extensions, conductive connections between said side circuits and their extensions, and means associated with said conductive connections to prevent the transfer of crosstalk and noise currents between the phantom circuit and side circuit extensions.

5. In a telephone circuit comprising side circuits together furnishing a phantom circuit and physical extensions of said side circuits and phantom circuit, a phantom-forming device connecting each side circuit and its extension and from which the phantom extension is led, means furnishing direct current paths through the phantom-forming device to connect the respective sections of the conductors of the side circuits, and means associated with said connecting means for preventing disturbances in the circuit extensions resulting from the establishment of the direct current paths.

6. A phantom circuit comprising side circuits and extensions thereof, phantom-forming devices inductively associating the side circuits with their extensions, conductive connections between said side circuits and their extensions, impedance included in said connections, and a bridge between the side circuit extensions at the phantom-forming devices.

7. In a telephone circuit comprising side circuits together furnishing a phantom circuit and physical extensions of said side circuits and phantom circuit, and a reflection-reducing device interposed between the phantom circuit and its physical extension and serving to prevent the transfer of disturbing current between the phantom circuit and the side circuit extensions.

8. In a telephone circuit comprising side circuits together furnishing a phantom circuit and physical extensions of said side circuits and phantom circuit, and an autotransformer interposed between the phantom circuit and its physical extension and having windings in series with the side circuit extensions.

9. The combination with the side circuit of a phantom circuit, said side circuit being provided with a terminal extension, of a phantom-forming device having line windings and extension windings, and a connecting device with windings joining said line and extension windings.

10. The combination with the side circuit of a phantom circuit, said side circuit being provided with a terminal extension, of a phantom-forming device having line windings and extension windings, and a transformer provided with windings connecting said line and extension windings.

11. The combination with two line circuits, of means for connecting said line circuits and forming a phantom circuit therefrom, physical extensions from the line circuits and phantom circuit, and a bridge between the line extensions at the connecting means.

12. The combination with two line circuits, of means for connecting said line circuits and forming a phantom circuit therefrom, physical extensions from the line circuits and phantom circuit, and a bridge between the line extensions at the neutral points therein.

13. The combination with two line circuits, of means for connecting said line circuits and forming a phantom circuit therefrom, physical extensions from the line circuits and phantom circuit, a bridge across each line extension, condensers in the bridges, and a short circuit between the line extensions from points between the condensers.

14. The combination with two line circuits, of means for connecting said line circuits and forming a phantom circuit therefrom, physical extensions from the line circuits and phantom circuits, and an autotransformer connecting each line circuit with its extension and having windings in a bridge of the phantom.

15. The combination with two line circuits, of means for connecting said line circuits and forming a phantom circuit therefrom, physical extensions from the line circuits and phantom circuit, and an autotransformer connecting each line circuit with its extension and having windings in a bridge of the phantom and other windings in the physical circuits.

16. Two physical circuits, a phantom repeating coil in each circuit, and an autotransformer joining the portions of each phantom repeating coil.

17. Two physical circuits and extensions thereof, a phantom repeating coil associating the sections of each circuit, a phantom circuit extension of different impedance from the phantom furnished by the two physical circuits, and an autotransformer having windings in the phantom and its extension and joining the sections of the physical circuits.

18. Two physical circuits and extensions thereof, a phantom repeating coil associating the sections of each circuit, a phantom circuit extension of different impedance from the phantom furnished by the two physical circuits, and an autotransformer having windings in the phantom and its extension and joining the sections of the physical circuits, the windings for the phantom being in a bridge of said phantom.

19. Two physical circuits and extensions thereof, a phantom repeating coil associating the sections of each circuit, a phantom circuit extension of different impedance from the phantom furnished by the two physical circuits, an autotransformer having windings in the phantom and its extension and joining the sections of the physical circuits, a bridge across each line circuit, and a condenser in the bridge.

20. Two physical circuits and extensions thereof, a phantom repeating coil associating the sections of each circuit, a phantom circuit extension of different impedance from the phantom furnished by the two physical circuits, an autotransformer having windings in the phantom and its extension and joining the sections of the physical circuits, the windings for the phantom being in a bridge of said phantom, and a condenser included in the bridge with the autotransformer windings.

21. Two physical circuits and extensions thereof, a phantom repeating coil associating the sections of each circuit, a phantom circuit extension of different impedance from the phantom furnished by the two physical circuits, an autotransformer having windings in the phantom and its extension and joining the sections of the physical circuits, the windings for the phantom being in a bridge of said phantom, balanced condensers included in each bridge with the autotransformer windings, and a short circuit connecting the bridges from points between the balanced condensers.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses, this 24th day of September, 1914.

FRANK H. FAY.
THOMAS SHAW.

Witnesses:
LLOYD ESPENSCHIED,
WALTER J. DODGE.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses, this 28th day of September, 1914.

JAMES J. PILLIOD.

Witnesses:
E. J. BENZING,
H. S. FOLAND.