

1,233,766.

Patented July 17, 1917.

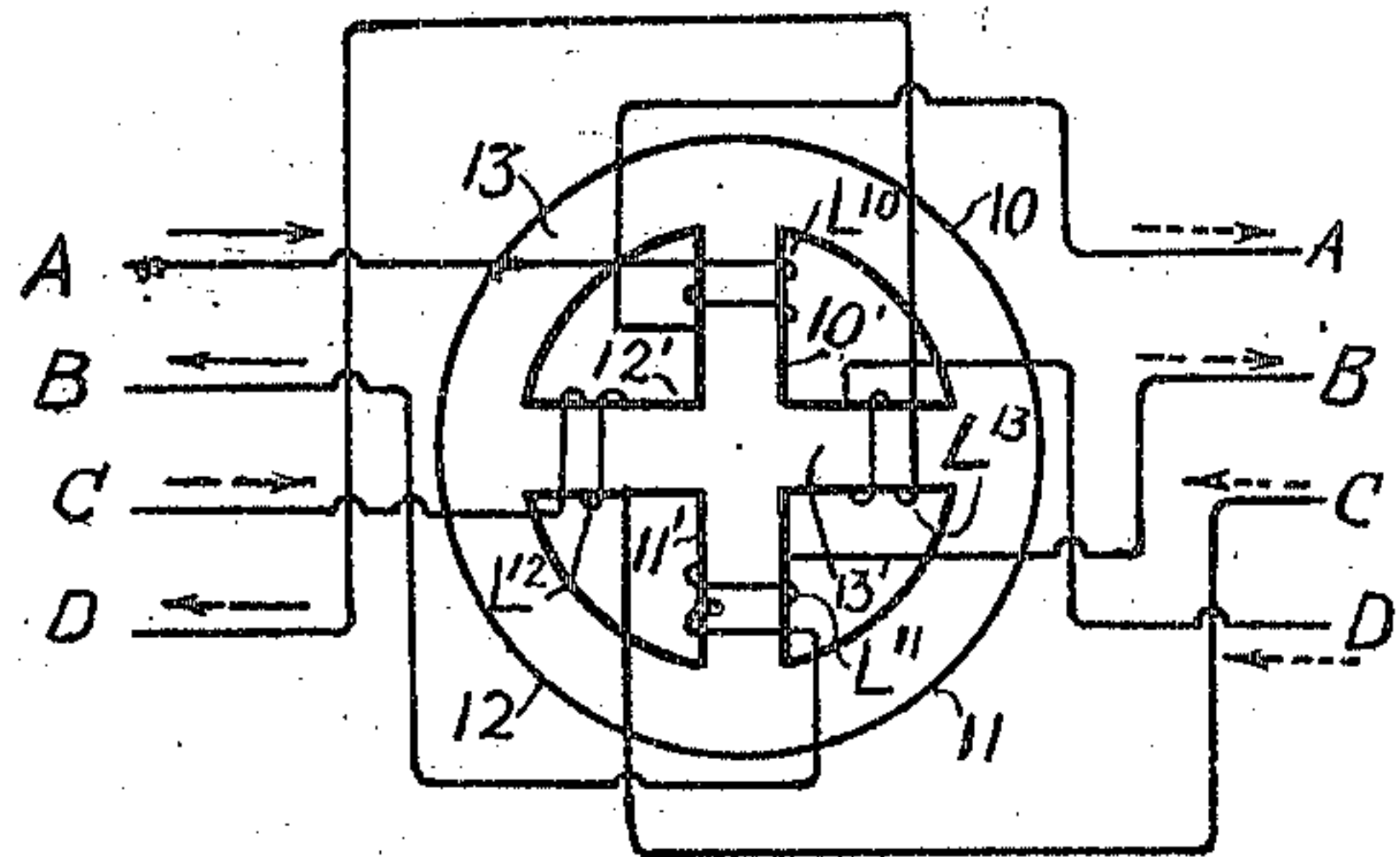


Fig. 1.

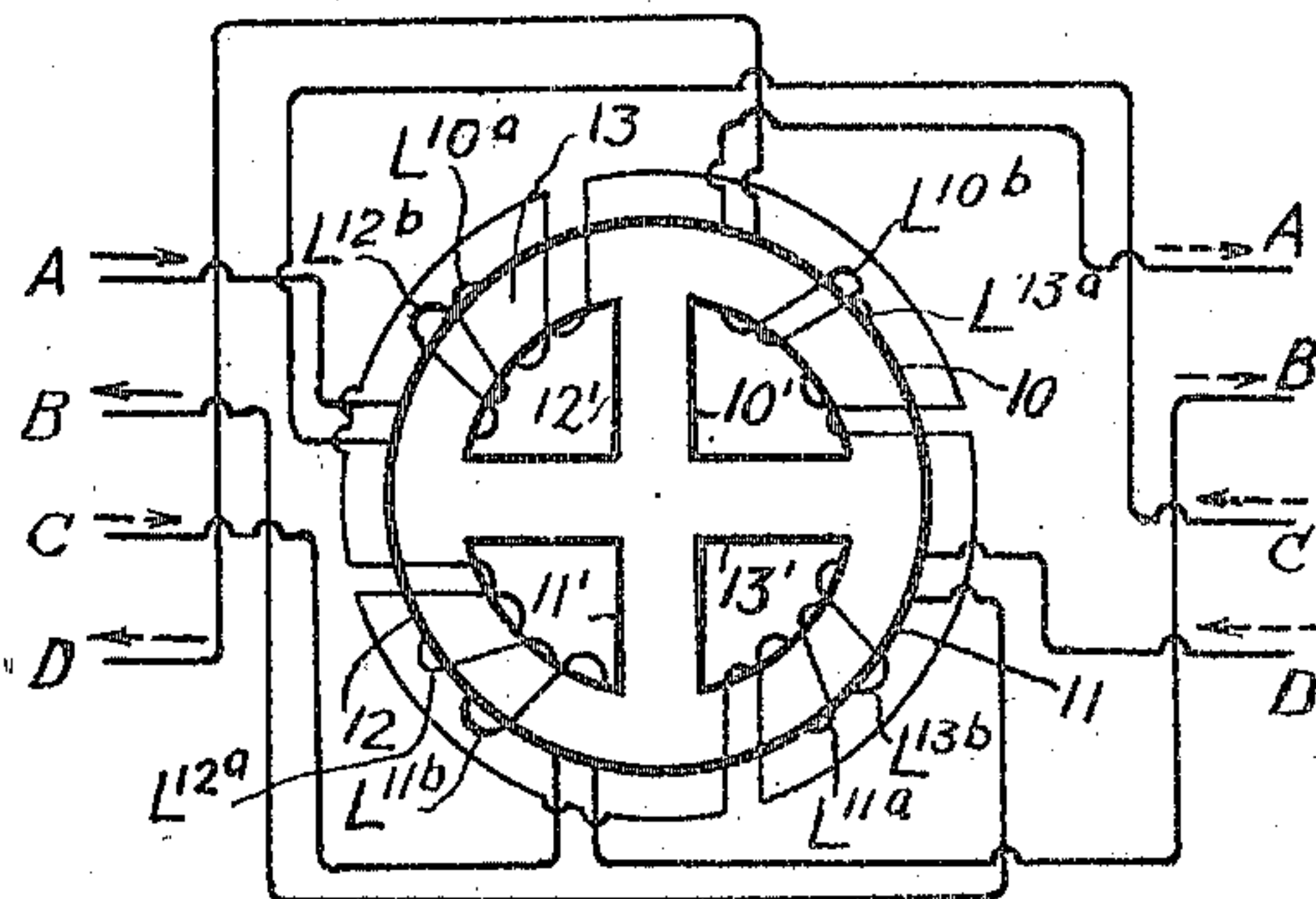


Fig. 4.

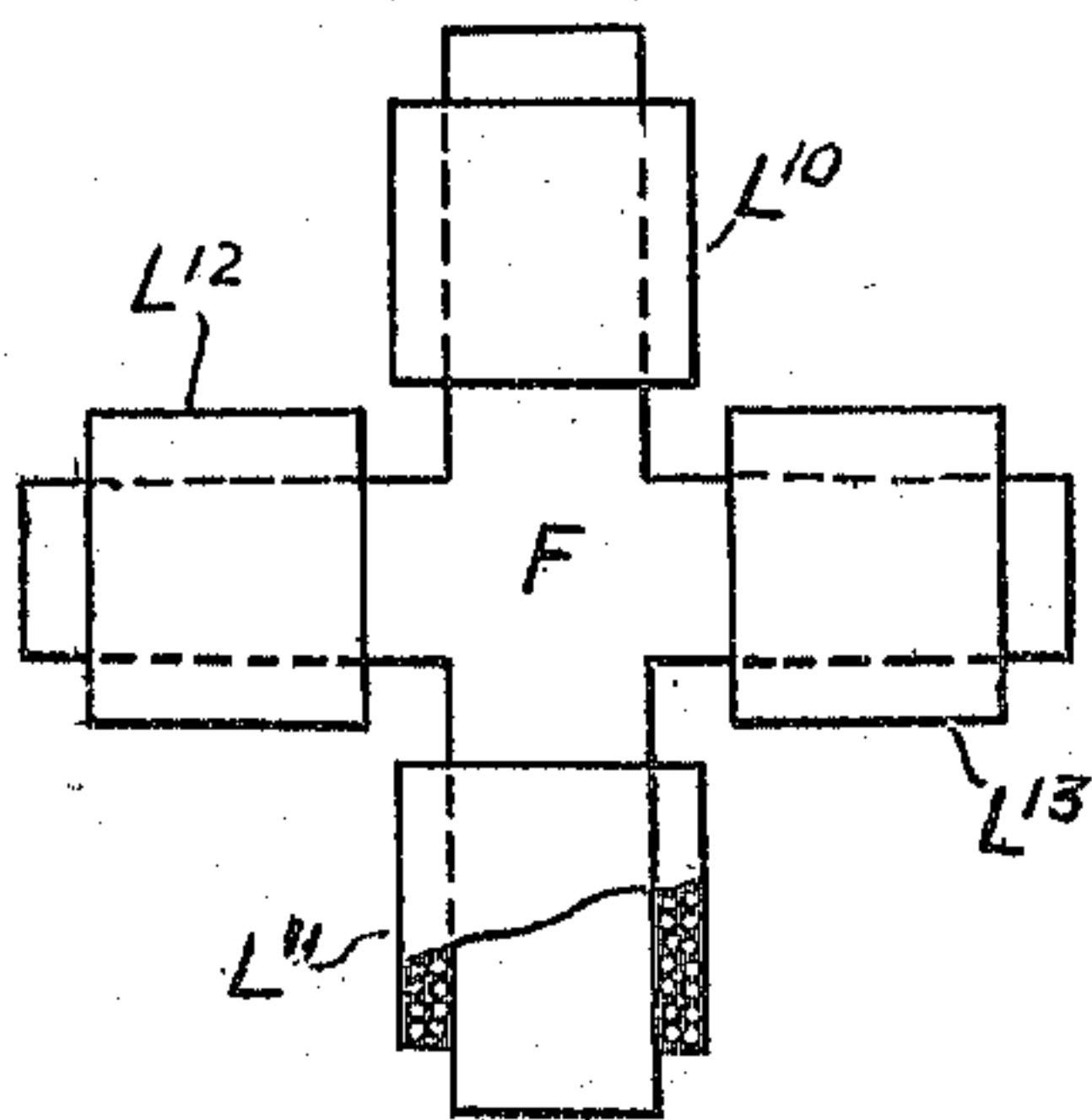


Fig. 5.

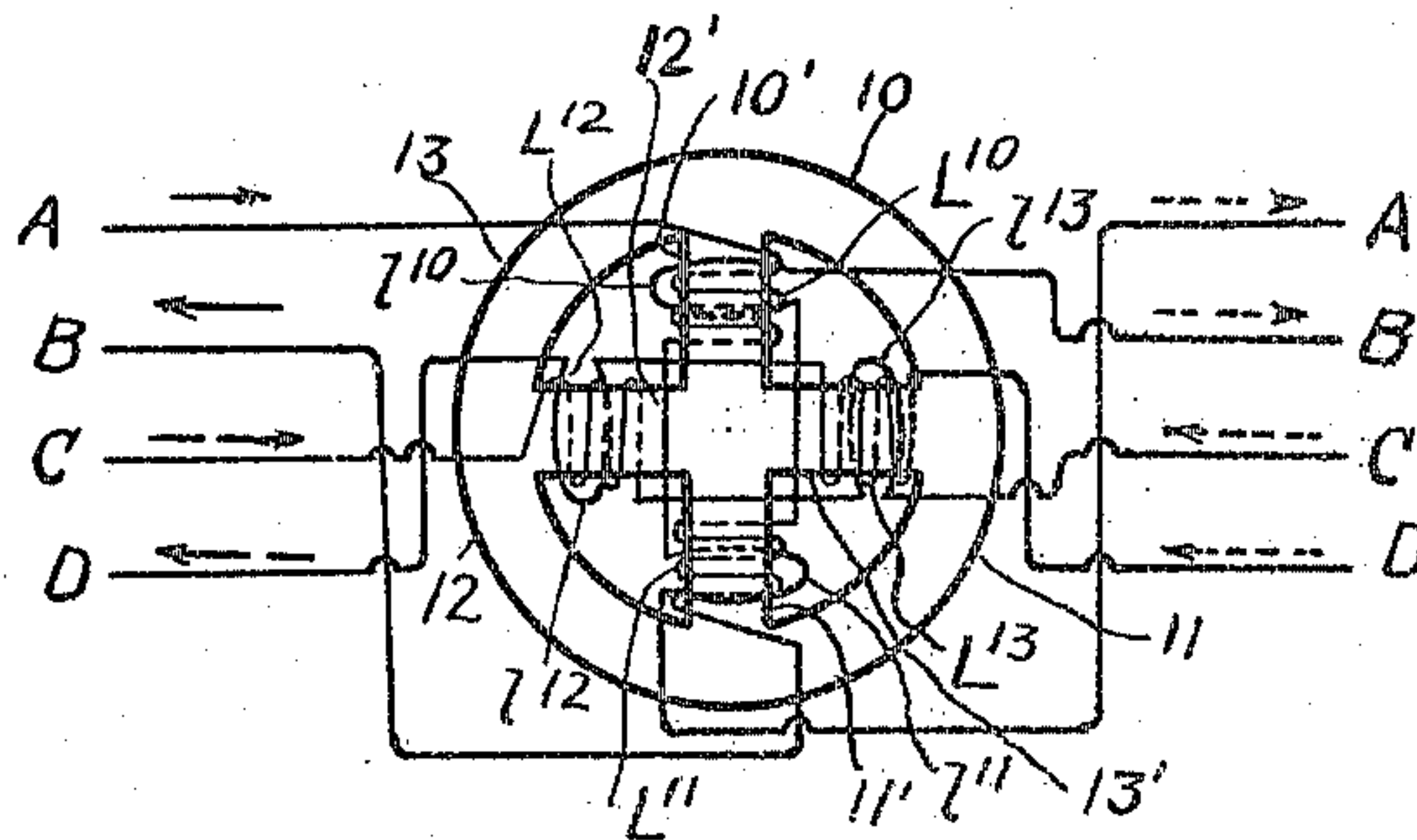


Fig. 6.

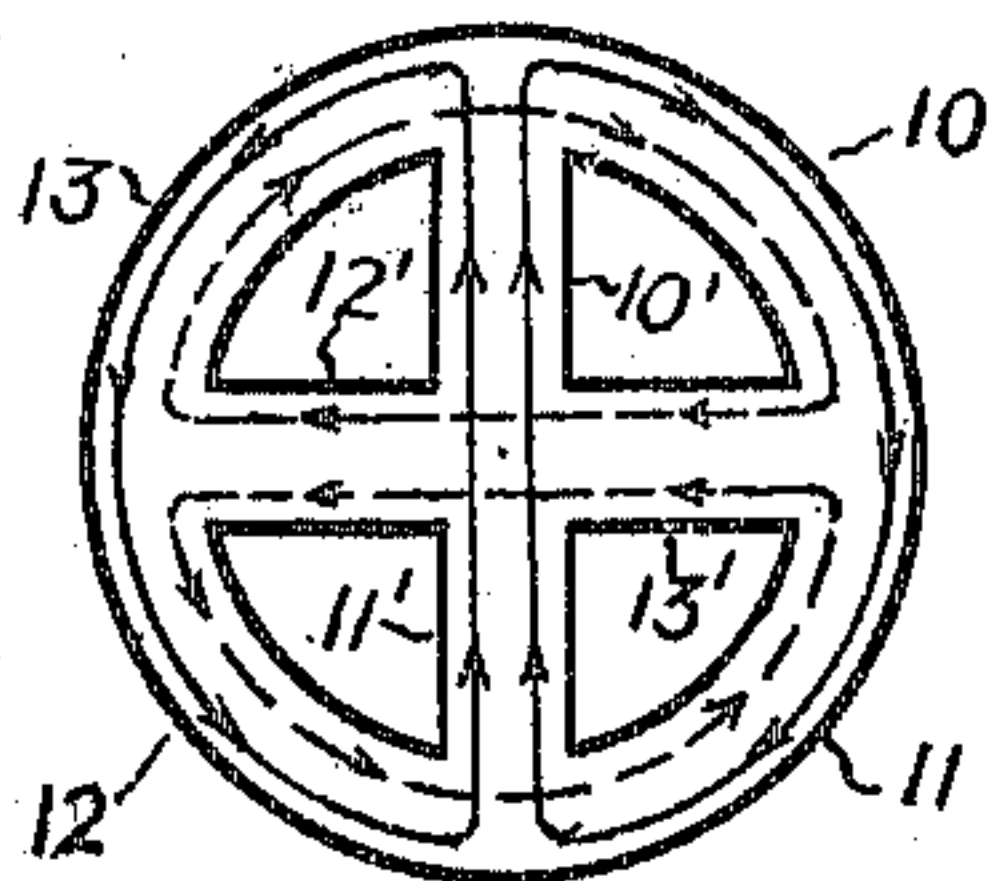


Fig. 2.

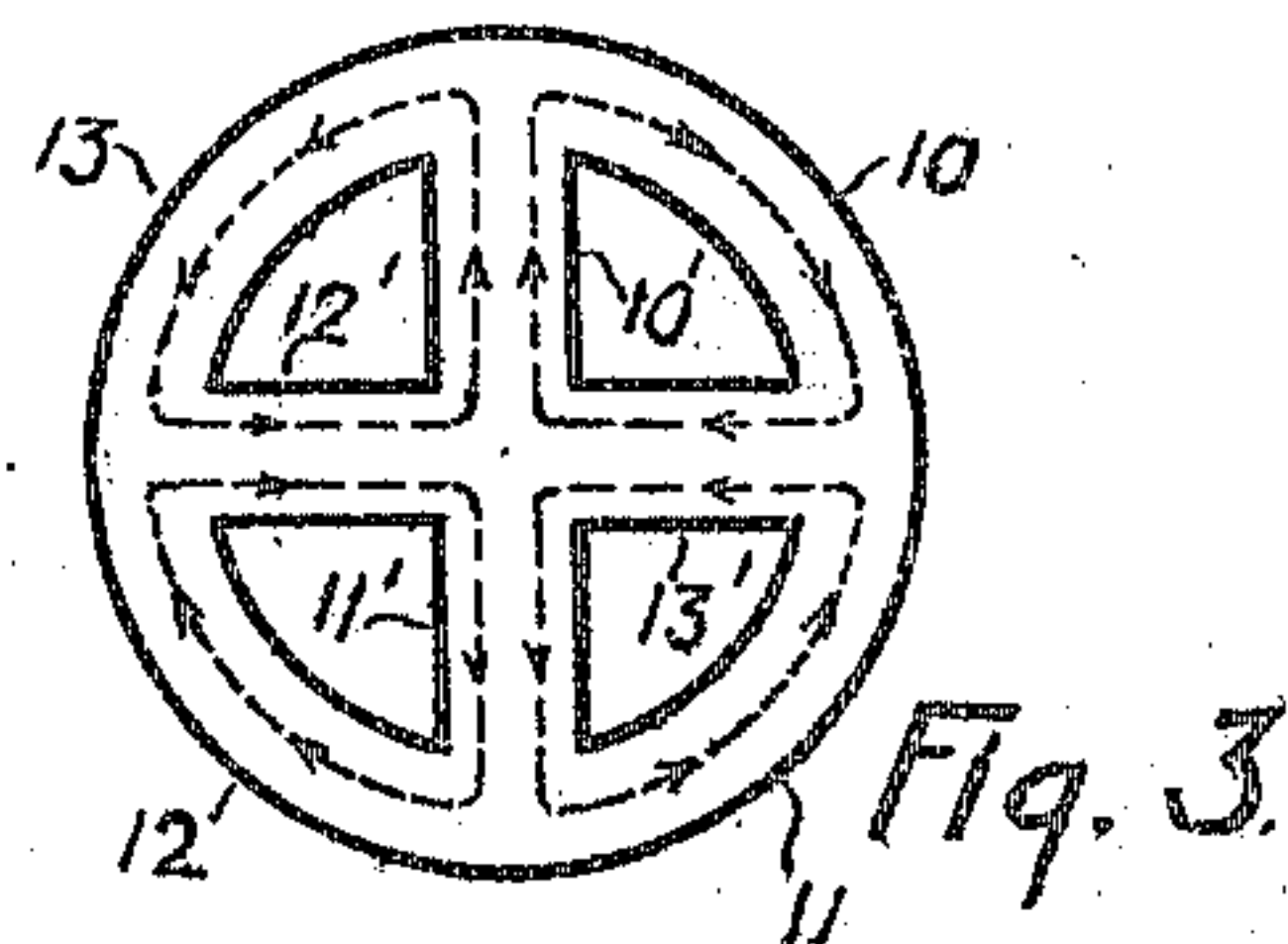


Fig. 3.

Inventor:
 Lloyd Espenschied.
 by Mauro, Cameron, Lewis & Mason Attys.

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

DUPLEX CIRCUIT.

1,233,766.

Specification of Letters Patent.

Patented July 17, 1917.

Application filed October 13, 1915. Serial No. 55,714.

To all whom it may concern:

Be it known that I, LLOYD ESPENSCHIED, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Duplex Circuits, of which the following is a specification.

Heretofore, in producing in duplex signaling circuits, consisting, for example, of two physical telephone circuits together furnishing a phantom circuit, inductance effects, such as are sought in loading to improve transmission, reducing reflection losses by autotransformers and conductively separating line sections by means of repeating coils, a separate inductance device has been employed in each of the circuits at every point where the effect is sought, the phantom devices being independent of those in the physical or side circuits. Since the side circuit current must traverse the windings of the phantom devices, it is subjected to resistance and other losses. The present invention avoids this by utilizing the effects in the devices in one class of circuits, as the sides, to produce like effects in the other class, as the phantom. Considering as one of the most valuable applications of the invention its use for loading duplex telephone circuits, it may be said that the standard toroidal loading coil is so designed, as to core form and winding disposition, that the windings neutralize one another's inductance for current peculiar to the circuit which they are not intended to load, and in which they are connected mutually opposing, and the devices in different circuits are also so related and with interposed media of such a character that the mutual inductances between them are negligible. In carrying out my invention, however, the windings belonging to each circuit are so loosely coupled inductively that this neutralization is but partial and the windings for different circuits are more closely coupled. Therefore inductance is introduced into both classes of circuits. Another feature of the invention consists in providing auxiliary means for varying the inductance effect of the device upon one or more of the circuits to enable the ratio of the inductance in the two classes of circuits to be controlled.

In the accompanying drawing, in which similar reference characters designate like parts throughout, Figure 1 illustrates diagrammatically one embodiment of the in-

vention applied to the loading of both physical and phantom circuits; Figs. 2 and 3 represent respectively the flux produced in the core of Fig. 1 by side circuit current and phantom circuit current; Fig. 4 shows another manner of disposing the line windings; Fig. 5 represents another form of the invention, in which the magnetic core is omitted; and Fig. 6 is similar to Fig. 1, with inductance ratio modifying windings added.

Referring to Fig. 1 of the drawing, the pairs of conductors A, B and C, D, represent portions of two telephone circuits in which flow talking currents, the direction of which is indicated by the full and dashed arrows, these physical or side circuits being combined in any convenient manner to furnish a third or phantom circuit traversed by talking current indicated by the dotted arrows. I have, in this instance, shown a unitary structure for loading both the side and phantom circuits. This comprises a core of magnetic material having portions or quadrants 10, 11, 12 and 13, equal in dimensions, arranged in the form of a symmetrical closed figure, this being illustrated as a toroid, though it may obviously be of other contour. At the junctions of the portions 10, 11, 12 and 13, which are preferably integral with one another, there are connected other portions 10', 11', 12' and 13', also preferably integral, which appear as radial arms separated from one another by 90°. In the organization of Fig. 1 the arms of the core may be considered as the primary core portions, carrying line windings L^{10} , L^{11} , L^{12} and L^{13} belonging respectively to the conductors A, B, C and D. These windings are preferably so connected that the inductances of the windings L^{10} and L^{11} are mutually aiding for the side circuit current in conductors A and B and the windings L^{12} and L^{13} similarly related for the side circuit current in the conductors C and D. Moreover, the pairs of windings L^{10} , L^{11} and L^{12} , L^{13} are mutually aiding for phantom circuit current. The relations between the inductances may be represented by the following simple equations:

$$L^s = 2(L + M) \quad (1)$$

$$L^p = L - M + 2N \quad (2)$$

Where L^s = total side circuit inductance; L^p = total phantom circuit inductance; L = self inductance of each line winding;

100

100

110

M =mutual inductance between line windings of the same side circuit; and N =mutual inductance between line windings of different side circuits.

From these equations it will be evident that with coils designed primarily to load the side circuits their influence upon the phantom is slight, since the mutual inductance M between the windings of the same side circuit acts against the self inductance L of the windings and because of the close coupling is practically as great, and the mutual inductance M between the windings of different side circuits, which would aid the self inductance, is negligible because of the construction and relation of the coils. In my invention the inductance $2N$ is made effective to load the phantom by increasing the closeness of the coupling with respect to the windings of the coils of different side circuits, while at the same time the negative loading effect of the mutual inductance M is reduced by decreasing the closeness of the coupling between windings of the coils of the same side circuit. This is accomplished by placing the windings L^{10} , L^{11} and L^{12} , L^{13} for the same side circuit upon independent members of a core structure which is unitary for both side circuits, as the cross-shaped arms $10'$, $11'$ and $12'$, $13'$, and by providing the core with branches 10 , 11 , 12 and 13 so arranged that the flux originating in any winding, is not confined to its companion winding, but is diverted in part through the windings belonging to the other side circuit. This will best be understood by reference to Figs. 2 and 3 of the drawings. For any instantaneous current peculiar to the side circuits, or flowing serially in each, the flux due to the windings L^{10} , L^{11} and L^{12} , L^{13} is represented in Fig. 2 by full and dashed arrows, respectively. It should be noted that the flux due to the windings of one side circuit does not link with the windings of the other, so that the side circuits are non-interfering. In Fig. 3 is represented in dotted lines the flux resulting from the phantom current, which passes serially through both side circuits with the windings of each in parallel. Here, for example, the flux leaving primary portions $10'$ and $11'$ of the core divides, flowing in opposite directions through the secondary portions 10 , 13 and 11 , 12 , respectively, and there unites and completes its circuit through the primary core portions $13'$ and $12'$. This linkage of flux between the windings of different side circuits gives the inductance N of the second equation. The portion of the phantom flux which links with one winding of a side circuit does not link with the companion winding. The remaining portion of the phantom flux, however, does thus link but in an opposite direction. The induced electromotive forces

in the side circuit pair due to the two effects thus neutralize one another, and the phantom and side circuits are therefore mutually non-interfering.

Instead of placing the line windings upon the arm portions of the core they may be disposed upon the outer portions 10 , 11 , 12 and 13 , as is illustrated in Fig. 4. But since, as appears from Figs. 2 and 3, the flux in the arms divides into two components extending in opposite directions about the toroid, it is necessary to employ two turns of winding upon the outer, or what is now the primary, portion for each turn used in the arrangement of Fig. 1 to obtain the same result. The windings of each conductor are therefore arranged in two sections, L^{10a} , L^{10b} ; L^{11a} , L^{11b} ; L^{12a} , L^{12b} ; and L^{13a} , L^{13b} , located respectively upon adjacent toroid quadrants with the windings of one side circuit staggered 90° with respect to the windings of the other side circuit. The two winding sections on each quadrant are preferably wound one above the other, one of the sections of each winding occupying an inner position on one quadrant and the other an outer position on the adjacent quadrant. The two sections for each conductor are connected mutually opposing, and the two sections for companion conductors, which are on adjacent core quadrants, are connected mutually aiding for side circuit current. The two superposed sections on each quadrant are connected mutually aiding for phantom current. The flux distribution and ratio of phantom to side circuit inductance are as in the organization of Fig. 1.

The generic conception of this invention does not require that a core of magnetic material be employed. The core structure may be what is termed the "air-core" type, which is such an arrangement as illustrated in Fig. 5. The line windings L^{10} , L^{11} , L^{12} and L^{13} appear mounted upon the arms of a cross-shaped frame F which may be of any suitable non-magnetic material, as wood. The relations between the windings and the flux created may be as is illustrated in Figs. 1 to 3; and though the magnetic coupling between the windings will, of course, be less, by suitably proportioning the windings the desired loading action may be obtained.

The mutual inductances which affect the electromagnetic balance between circuits are those between line windings of different side circuits. In order that the component circuits be balanced, and hence non-interfering in this respect, it is necessary that there be no resultant mutual inductance between the three circuits; that is, that the four mutual inductances between the four line windings neutralize one another. To provide that the effective mutual inductance between the cir-

cuits be zero, two of the four mutual inductances must balance the other two. In the arrangements described, the windings of one side circuit are symmetrically disposed with respect to the windings of the other side circuit, and are so poled that two act oppositely to the other two for either the side circuit connection in both side circuits (the condition for zero side-to-side crosstalk) or for the side circuit connection in one circuit and the phantom circuit connection in the other circuit (the condition for zero phantom-to-side crosstalk). All are therefore theoretically balanced as to mutual inductances. They are also, by symmetry of design, balanced electrostatically and with respect to effective resistance and self inductance. In consequence of this, there will be theoretically no crosstalk between the several circuits of the loading unit.

In loading phantom and side circuits a ratio of 0.6 between the respective inductances is often desired, while none of the plans hereinbefore described will give a higher ratio than 0.5. To enable this ratio to be so controlled that the proper relation may be established, I provide auxiliary means for varying either or both the side circuit and phantom circuit inductances. As illustrated in Fig. 6, this means takes the form of auxiliary windings L^{10} , L^{11} , L^{12} and L^{13} . In the present instance it is assumed that the ratio of the phantom to the side circuit inductance is to be increased. In such case, though the auxiliary windings may be upon either of the core portions, it is preferable to place them upon arms 10', 11', 12' and 13' of the core which are traversed by all the flux due to the phantom circuit. This requires but half as many turns of auxiliary windings as would be the case were they upon the portions 10, 11, 12 and 13, in which the phantom flux is divided (see Figs. 2 and 3). Considering any one of the four line conductors, as A, it is connected to the outer terminal of the main winding L^{10} upon the arm 10' of the core, with the inner extremity of this winding joined to the inner end of the auxiliary winding L^{11} , situated upon the arm 11' of the core and being wound in the opposite direction to L^{10} . The line conductor A continues from the outer terminal of the winding L^{11} . Line conductors B, C and D are similarly joined to the main windings L^{11} , L^{12} and L^{13} upon the core arms 11', 12' and 13', respectively, and to the auxiliary windings L^{10} , L^{13} and L^{12} upon the core arms 10', 13' and 12', respectively. The auxiliary windings when thus located are placed over the primary windings and are closely coupled therewith inductively, so as to cause a maximum difference in their net inductance for the phantom and side circuit currents. The auxiliary windings are connected in such a manner that their induc-

tances act simultaneously to decrease the side circuit inductance and to increase the phantom circuit inductance, the ratio sought being obtained by altering the number of turns of these modifying windings.

Each auxiliary winding may be applied to the core member in two sections, so arranged that the relation between the sections causes the inductances for one class of current, say in the side circuits, to neutralize one another, while for the other circuit, as the phantom, the inductances are added to each other and those of the primary windings. Here, however, one of the sections may be, in effect, merely a continuation of the corresponding primary windings and is most conveniently provided by increasing the number of turns of the latter. This arrangement is therefore not separately illustrated.

The division of line windings, of a branch magnetic circuit loading coil, into separate sections and the distribution of said sections upon the associated core, as illustrated for example in Fig. 4 of the drawings, is not claimed herein, but relates to a different invention claimed in my copending application Serial No. 55,716, filed October 13, 1915, renewed June 14, 1917, Serial No. 174,778. Other specific embodiments of the invention herein claimed are disclosed in my copending applications Serial Nos. 55,715, 55,716 (renewal Sr. No. 174,778) and 55,717, filed October 13th, 1915.

I claim:

1. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a magnetic core having primary connected portions and secondary connected portions connected thereto, there being line windings upon the primary portions and the secondary portions furnishing continuous return paths for flux from the primary portions.

2. The combination of two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a magnetic core having primary connected portions and secondary connected portions connected thereto, there being line windings confined to the primary portions and the secondary portions furnishing continuous return paths for flux from the primary portions.

3. The combination of two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a magnetic core having a plurality of connected portions, another set of core portions connected to each other and connecting the junctions of the first-named portions, and a winding for each line conductor, said windings being on one set of core portions.

4. The combination of two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a magnetic core having a plurality of portions connected to form a closed figure, another set of core portions connected to each other and connecting the junctions of the first-named portions, and a winding for each line conductor, said windings being located on said second-named portions.

5. A duplex circuit consisting of four conductors, and an inductance device comprising a magnetic core having four connected portions and other core portions extending from the junctions of the first-named portions, and a winding upon each of the second-named core portions and being included in the conductors of the duplex circuit.

6. The combination of two physical circuits consisting of line conductors together furnishing a phantom circuit, of a loading coil comprising a core portion of toroidal form, a plurality of other core portions joining opposite sides of the toroid, and a winding in each line conductor, said windings being upon said other core portions.

7. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a core portion of toroidal form and portions joining opposite sides of the toroid, and a winding for each line conductor, said windings being situated upon the core portions separated by 90° from one another.

8. The combination of two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a core portion of toroidal form and radial portions situated 90° from one another and joining opposite sides of the toroid, and a winding for each line conductor, said windings being situated on said radial portions.

9. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of windings included in the conductors of each physical circuit in oppositely disposed pairs, the pairs of windings in the same physical circuit being connected to produce loading effects therein and the windings of different circuit pairs being closely coupled inductively to produce loading effects in the phantom circuit.

10. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of windings included in the conductors of each physical circuit in oppositely disposed pairs, the windings belonging to each physical circuit being loosely coupled and the windings belonging to different circuits being closely coupled, said windings producing inductance

effects in the physical circuits and also producing inductance effects in the phantom circuit.

11. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of windings included in the conductors of each physical circuit in oppositely disposed pairs, the windings belonging to each physical circuit being loosely coupled and the windings belonging to different circuits being closely coupled, the windings of the circuit pairs being separated by 90° from one another, said windings being adapted to produce inductance effects in the physical circuits and also to produce inductance effects in the phantom circuit.

12. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a magnetic core having opposite primary portions and connecting portions, and a winding for each line conductor, the windings of the conductors of the two lines being respectively situated in pairs upon opposite pairs of primary core portions.

13. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of an inductance device comprising a magnetic core having opposite primary portions and connecting portions, and a winding for each line conductor, the windings of the conductors of the two lines being respectively situated in pairs upon opposite pairs of primary core portions and the pairs of windings being separated by 90° from one another.

14. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of windings included in the conductors of each physical circuit in oppositely disposed pairs, the windings belonging to each physical circuit being loosely coupled and the windings belonging to different circuits being closely coupled, said windings producing inductance effects in the physical circuits and also producing inductance effects in the phantom circuit, and means for varying said inductance effects.

15. The combination with two physical circuits consisting of line conductors together furnishing a phantom circuit, of windings included in the conductors of each physical circuit in oppositely disposed pairs, the windings belonging to each physical circuit being loosely coupled and the windings belonging to different circuits being closely coupled, said windings producing inductance effects in the physical circuits and also producing inductance effects in the phantom circuit, and means cooperating with said inductance means for varying the loading effect upon one of said circuits.

16. The combination with line conductors, of a plurality of windings producing an inductance effect in certain of said conductors, said windings being associated to produce another inductance effect, and a winding auxiliary to the other windings adapted to partially neutralize one of said inductance effects.

17. A plurality of members having windings and producing inductance effects, said members being associated to produce still another inductance effect, and auxiliary windings for partially neutralizing the last-named inductance effect.

18. In a duplex circuit, the combination with windings for producing a loading effect, said windings being associated to produce another distinct loading effect, of auxiliary windings associated with those first-named and adapted to partially neutralize one of said loading effects to modify the relation of such loading effects.

19. An inductance device comprising a core having a plurality of portions, other core portions connecting those first-named, inductance windings upon one set of core portions, and inductance controlling windings upon the core portions.

20. An inductance device comprising a core having a plurality of portions, other core portions connecting those first-named, inductance windings upon one set of core portions, and inductance controlling windings upon the same set of core portions.

21. A duplex circuit consisting of two physical circuits and a phantom circuit furnished thereby, of a plurality of primary inductance windings for loading a circuit, said windings being associated with one another to also load another of the circuits, and auxiliary windings associated with the primary inductance windings to modify their loading effect.

22. A duplex telephone circuit consisting of two physical circuits and a phantom furnished thereby, a plurality of inductance members adapted to load the physical circuits, said members being inductively related to one another whereby the phantom circuit is also loaded, and inductance controlling windings associated with the members for modifying their loading effect upon the phantom.

23. A loading coil comprising a core portion of toroidal form, a plurality of other core portions joining the sides of the toroid, primary inductance windings upon said other core portions, and auxiliary inductance windings located outside the primary windings.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses, this 27th day of September, 1915.

LLOYD ESPENSCHIED.

Witnesses:

CHAS. G. HEISER, Jr.,
A. C. FRANCA.