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M. K. ZINN

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PHANTOM TELEPHONE CIRCUIT

Filed June 16, 1931

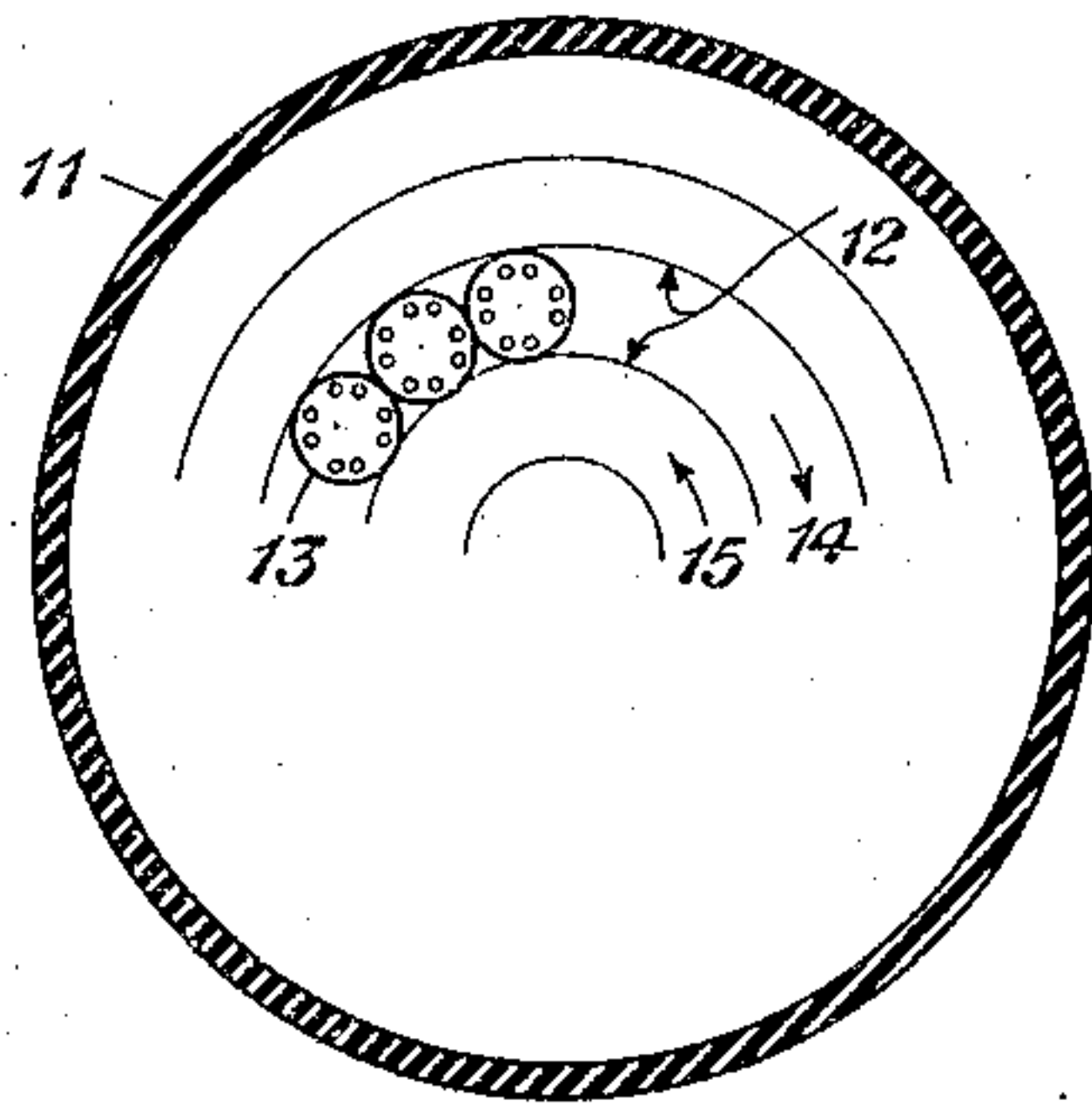


Fig. 1

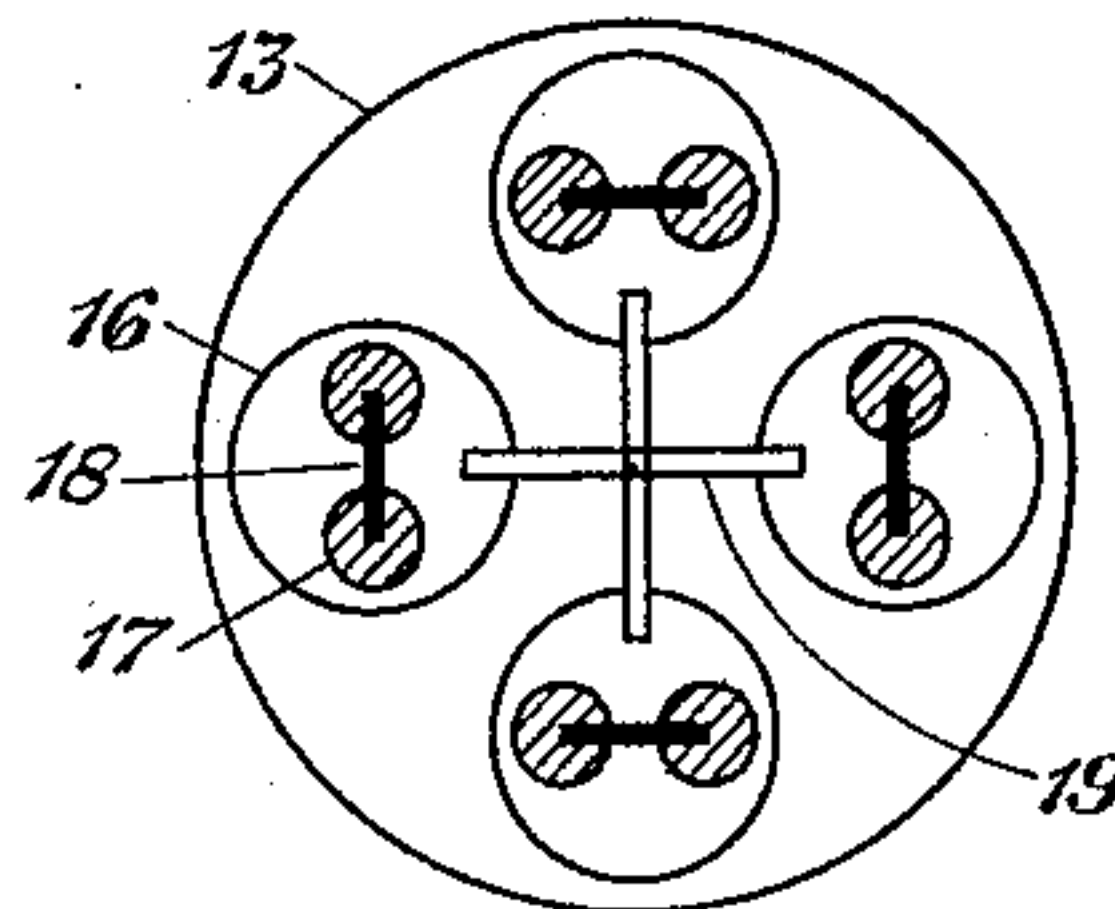


Fig. 2

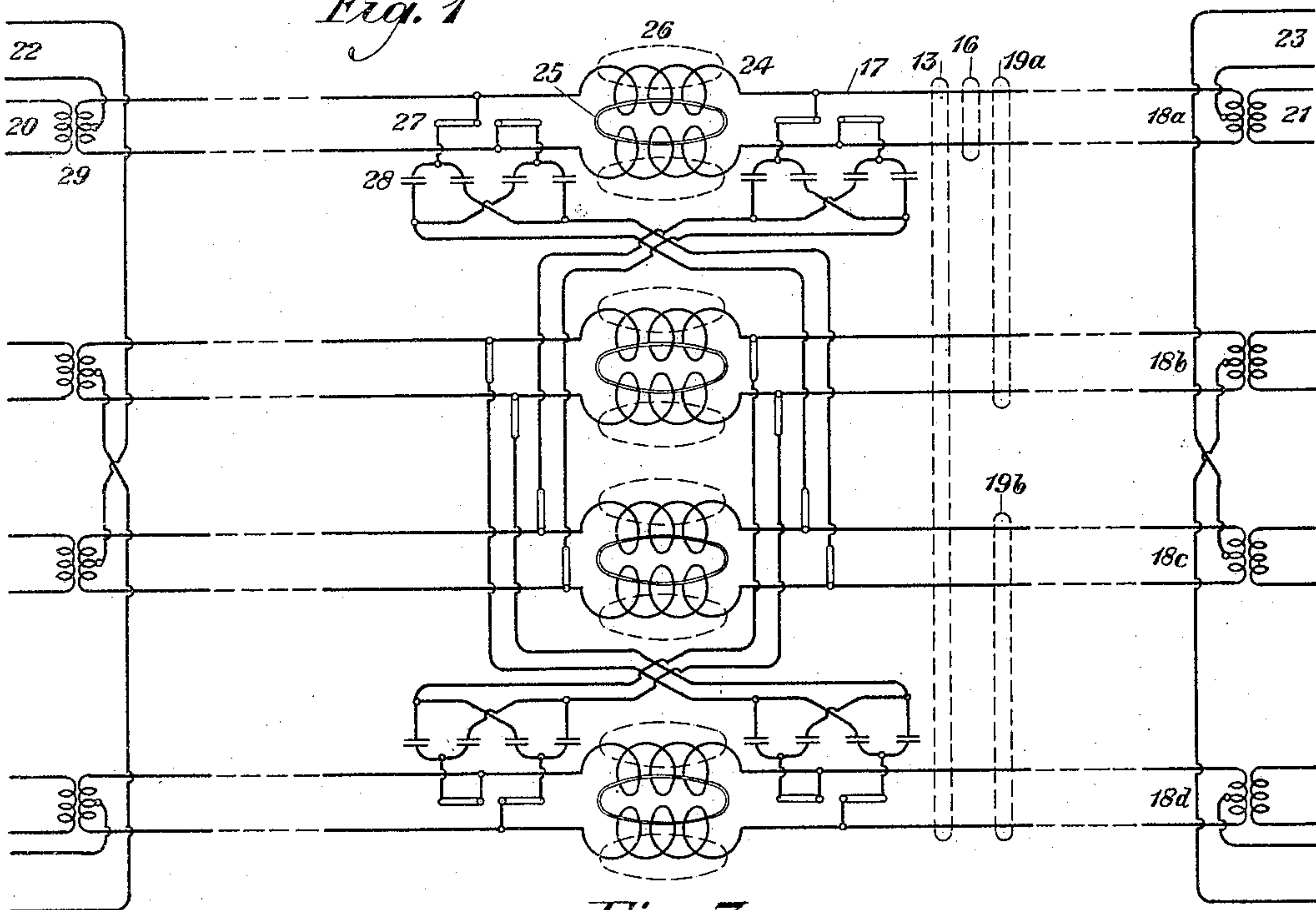


Fig. 3

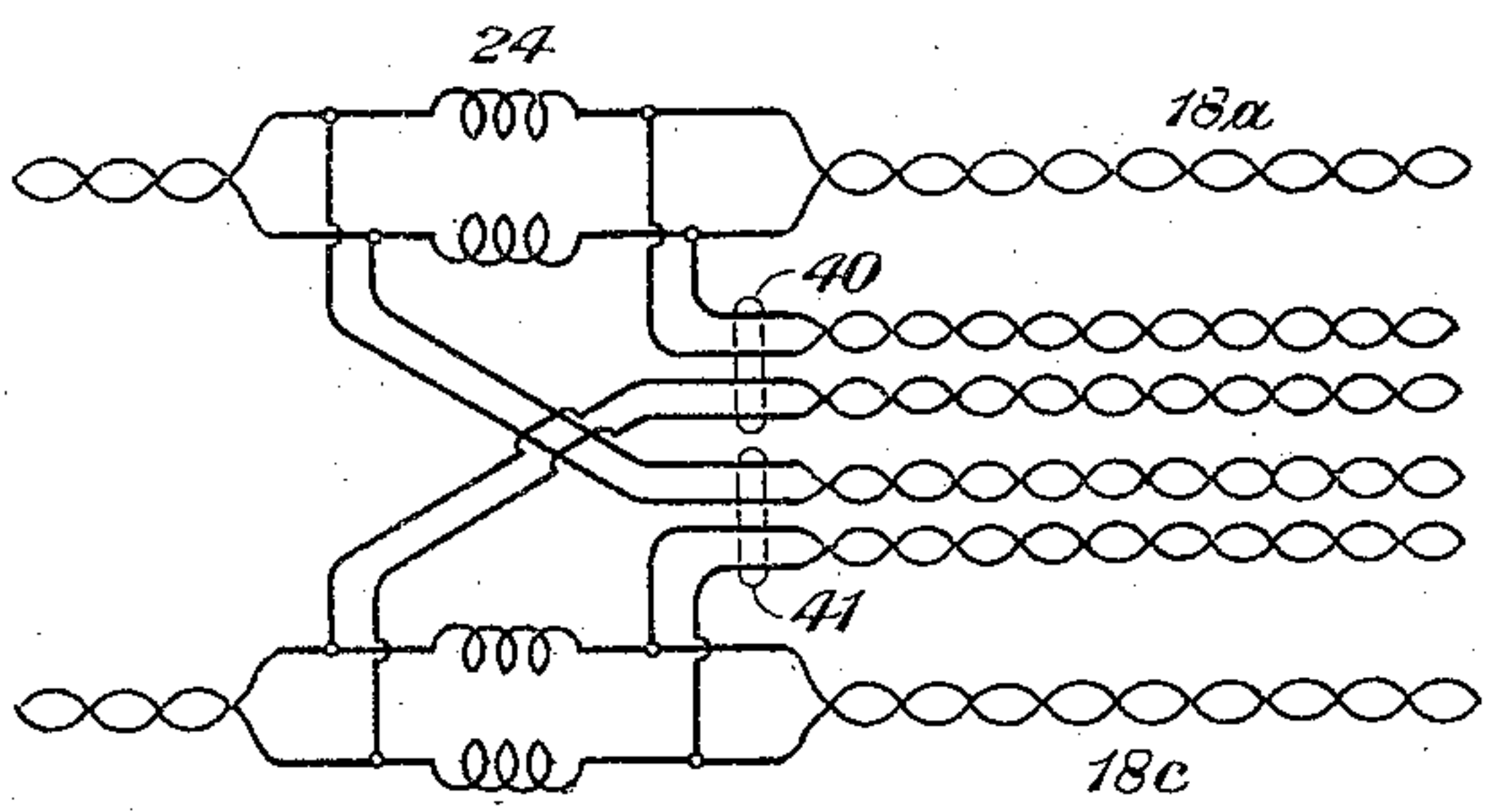


Fig. 5

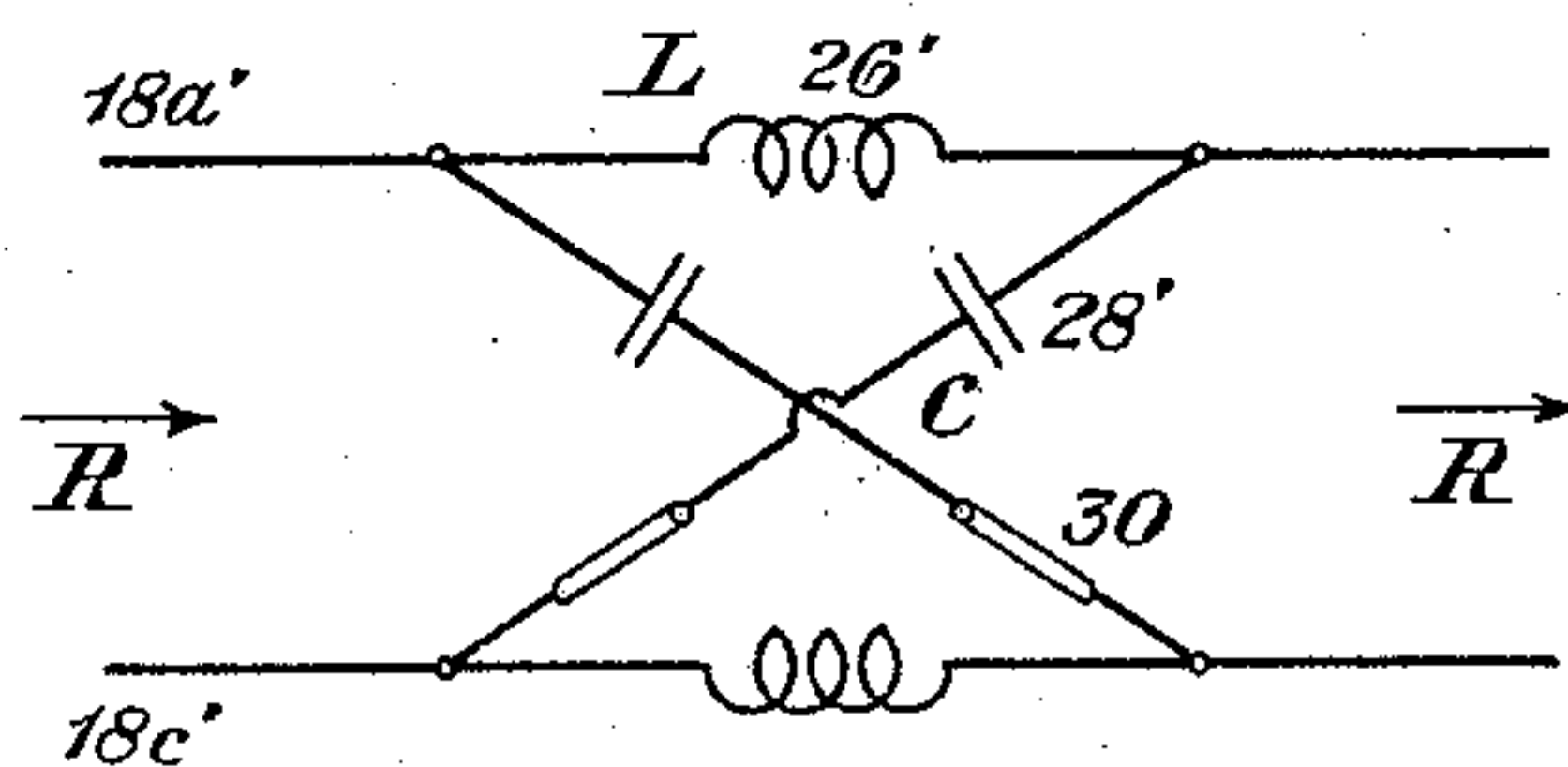


Fig. 4

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PHANTOM TELEPHONE CIRCUIT

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An object of my invention is to provide apparatus and a corresponding method for reducing impedance irregularities in transmission circuits. Another object of my invention is to combine certain added reactances with a necessary reactance in a transmission line so as to form a network whose impedance will be equal to the characteristic impedance of the line. Still another object of my invention is to provide added reactance elements to form a network that shall obviate the impedance irregularity in a phantom circuit due to leakage inductance in the loading coils of the side circuits. All these objects of my invention and other objects and advantages will become apparent on consideration of the specific example of practice in accordance with the invention which I disclose in this specification. It will be understood that this disclosure relates principally to this particular example of the invention, and that the scope of the invention will be indicated in the appended claims.

Referring to the drawing, Figure 1 is a diagrammatic cross-section of a multi-conductor cable built up of "spiral-8" units; Fig. 2 is a diagrammatic cross-section in more detail of one spiral-8 unit; Fig. 3 is a circuit diagram showing the circuits and certain associated elements of apparatus for one spiral-8 unit in the cable; Fig. 4 is a simplified diagram of a certain type of "lattice network"; and Fig. 5 is a diagram showing practical means for making compensation and adjustment according to my invention.

The cable having the sheath 11 consists of coaxial layers 12 of multi-conductor units 13. All these units 13 in one layer 12 are disposed in right-hand helical formation, as indicated by the arrow 14, but the units of the adjacent concentric shells are disposed in left-hand helices, as indicated by arrow 15. Thus proceeding along a radius of the cable, the successive layers are disposed alternately in right and left-hand helices. In this way the crosstalk between one layer and another layer is minimized.

Each spiral-8 unit 13 consists of four twisted pairs 16, these pairs being twisted together to form a spiral-8. The two con-

ductors 17 of a single pair 16 form a "side circuit" which may be used for ordinary telephone purposes. In Fig. 2 each solid black bar 18 joining the conductors 17 indicates symbolically such a side circuit. Two opposite pairs of side circuits in the spiral-8 are combined to form a phantom circuit. Thus in each spiral-8 there are four side circuits and two phantom circuits. These two phantom circuits are indicated in Fig. 2 by the open or light face bars 19.

The diagram of Fig. 3 may be referred to as a kind of developed side elevation of Fig. 2. A single side circuit may be seen extending from the terminal pair 20 to the terminal pair 21 with repeating coils interposed as at 29. In the usual way, taps are taken from the mid-points of the windings of the repeating coils 29, and thus from the conductor terminals 22 at one end a phantom circuit may be traced to the conductor terminals 23 at the other end.

The side circuits such as 20—21 have loading coils 24 at regular intervals. The normal magnetic circuit for the loading coil 24 is indicated by the heavy line 25 in Fig. 3. For normal side circuit currents the windings of each coil are series aiding in the production of magnetic flux around the magnetic circuit 25. But the magnetomotive forces due to the two windings on one core buck each other for phantom circuit current and accordingly there will be some leakage flux, so that there will be lines of force such as 26 that will link with one of the windings of the coil 24 but not with the other.

For convenience of explanation, switches are shown as at 27; let it be assumed that these switches are all opened. Under these circumstances the leakage flux for the phantom circuit currents indicated by the dotted lines 26, will correspond to a degree of effective loading in the phantom circuit 22—23. A little loading in this phantom circuit might not be objectionable if it were correctly proportioned. But the inductive reactance due to the leakage flux is a residual quantity and will be quite variable. The side circuit loading coils can be paired with respect to their leakage inductances in the phantom circuit so as to insure longitudinal

balance; but the inductance in the phantom circuit will then vary from one loading point to another. This irregularity will result in impedance irregularities which will increase the far-end crosstalk in the phantom circuit by reflecting a certain proportion of the near-end crosstalk.

To obviate this difficulty, as will be explained more in detail presently, I introduce the condensers 28 in cross-connections between the side circuits through the switches 27 shown in Fig. 3. The principles involved in this arrangement may be explained with reference to Fig. 4.

Suppose $18a'$ and $18c'$ are the two conductors of a long transmission line which is normally of characteristic impedance R , but that in each conductor there is interposed a coil 26' of inductance value L . If the switches 30 are open, the inductances L will cause reflection of current waves traveling along this line.

By making lattice cross-connections through the condensers 28 and switches 30, as shown in Fig. 4, and giving the condensers the proper capacity values C , the impedance looking into the network from one side can be made equal to R , provided the network is terminated on the other side by the impedance R , as is approximately the case for a long line. Thus the impedance irregularity is corrected and the lattice network comprising the inductances L and capacities C acts only as a phase shifter, aside from a slight loss due to the necessary resistance in the windings of the coils. The capacity C must be such that the formula

$$R = \sqrt{L/C}$$

will be satisfied. As explained above L will have different values from one loading point to another and accordingly C will have corresponding different values.

We may consider that $18a'$ in Fig. 4 represents the phantom conductor formed by the pair $18a$ in Fig. 3, and similarly $18c'$ represents the other conductor of the same phantom which is formed by the pair $18c$. L or 26' represents the leakage inductance indicated in Fig. 3 by the dotted lines 26. 28' or C , in Fig. 4, represents the capacity between the two conductors of the phantom circuit that is afforded in Fig. 3 by the four equal condensers 28. It will be seen that between the two sides of the pair $18a$ and the two sides of the pair $18c$, in Fig. 3, there are four possible cross-connections and accordingly there are four equal condensers 28, one in each of these cross-connections, and each providing one-quarter of the effective capacity represented by C in Fig. 4.

A practical procedure for getting the desired capacities 28 is indicated in Fig. 5 where two short lengths of ordinary quads 40 and 41 are provided as stubs. The ends

of the eight conductors of these two quads are connected to the four conductors of the phantom circuit at the sides of the loading coil windings, as shown in Fig. 5. For phantom circuit currents there will be no electromotive force across the conductors of a single pair in Fig. 5, but there will be an electromotive force across from pair to pair of the same quad, and it will be seen that the capacity effect due to this last mentioned electromotive force gives the diagonal cross-capacities corresponding to the C 's of Fig. 4. For side circuit currents, the twisted stub pairs will give capacity, but this will be no more than for an equal length of line conductor pair and hence will be relatively insignificant. If the quads are inconveniently long, convenient lengths can be assembled in parallel, as by using a section of stub cable and as many quads therein as found desirable.

Instead of completely neutralizing all the phantom circuit reactance due to the leakage inductance of the coils, an alternative procedure is to neutralize only a part of such inductance reactance so as to equalize the reactance at all loading points. To this extent the phantom circuit becomes a lightly loaded line, but it avoids the serious disadvantage of being irregularly loaded, and thus involves no reflection effects due to impedance irregularities.

I claim:

1. In combination, two loaded side circuits and a phantom circuit, and means associated with the loading coils to neutralize their leakage inductance reactance in the phantom circuit.

2. In combination, a circuit having an outgoing conductor and a return conductor, an inductance coil having series aiding windings in said conductors, and means to neutralize the leakage inductance reactance of said windings when the said conductors are utilized in parallel.

3. In combination, a circuit having an outgoing conductor and a return conductor, an effective reactance element in said circuit in balanced relation with respect to said conductors, said element being ineffective except for a small residual effect when the conductors are utilized in parallel, and means associated therewith to neutralize said residual effect.

4. In combination, two loaded side circuits and a phantom circuit, and condensers associated with the loading coils to neutralize their leakage inductance reactance in the phantom circuit.

5. In combination, two loaded side circuits and a phantom circuit, lattice cross-connections at each loading coil from each conductor of one side circuit to each conductor of the other side circuit, and condensers in these connections to neutralize the leakage induc-

tance reactance of the loading coils in the phantom circuit.

6. In combination, two loaded side circuits and a phantom circuit, lattice cross-connections at each loading coil from each conductor of one side circuit to each conductor of the other side circuit, and reactance elements in these connections to neutralize the leakage inductance reactance of the loading coils in the phantom circuit.

7. In combination, two loaded side circuits and a phantom circuit, and at each loading coil means connecting across from one side circuit to the other to neutralize the leakage inductance reactances of the coils in the phantom circuit.

8. In combination, two loaded side circuits and a phantom circuit, and condensers at the loading coils connected in lattice arrangement from the conductors of each side circuit to the conductors of the other side circuit, subject to the formula

$$R = \sqrt{L/C}$$

where R is the characteristic impedance of the phantom circuit line, L is the leakage inductance of a loading coil in the phantom circuit and C is the capacity in one of the lattice cross connections from one side circuit to the other.

9. A cable comprising spiral-8 units, each such unit consisting of four twisted pairs, the opposite pairs being utilized for two phantom circuits, loading coils in the four side circuits of each spiral-8 unit, at each loading coil station, lattice connected condensers between the pairs of each phantom circuit to neutralize the leakage inductance reactance of the coils in the phantom circuits.

10. In combination, two loaded side circuits and a phantom circuit, the loading coils of the side circuits having unequal leakage inductance reactance in the phantom circuit from point to point, and means to neutralize a part of such reactance at each loading point so as to equalize the reactance at all the loading points.

11. In combination a circuit having an outgoing conductor and a return conductor, and effective reactance elements in said circuit each in balanced relation with respect to said conductors, and means to equalize the effect of said elements when the said conductors are utilized in parallel.

12. The method of neutralizing the leakage in inductance reactance effect of side circuit loading coils in a phantom circuit which consists in developing lattice connected capacity reactance effects across from side circuit to side circuit at the loading coils.

13. The method of correcting for impedance irregularities due to unequal leakage inductances of the side circuit loading coils in a phantom circuit which consists in neutralizing a part of the corresponding reactance

at each loading point so as to equalize the remaining unneutralized inductance reactances.

14. The method of correcting for impedance irregularities due to unequal leakage inductances of the side circuit loading coils in a phantom circuit which consists in developing cross-connected capacity reactances in sufficient amount at each loading point so as to neutralize part of the corresponding reactance and thereby equalize the remaining unneutralized inductance reactances.

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

MANVEL K. ZINN.

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