T. SHAW.

MEANS FOR REDUCING REFLECTION LOSSES IN PHANTOM CIRCUITS.

APPLICATION FILED FEB. 28, 1913.

1,092,957.

Patented Apr. 14, 1914.

2 SHEETS—SHEET 1.

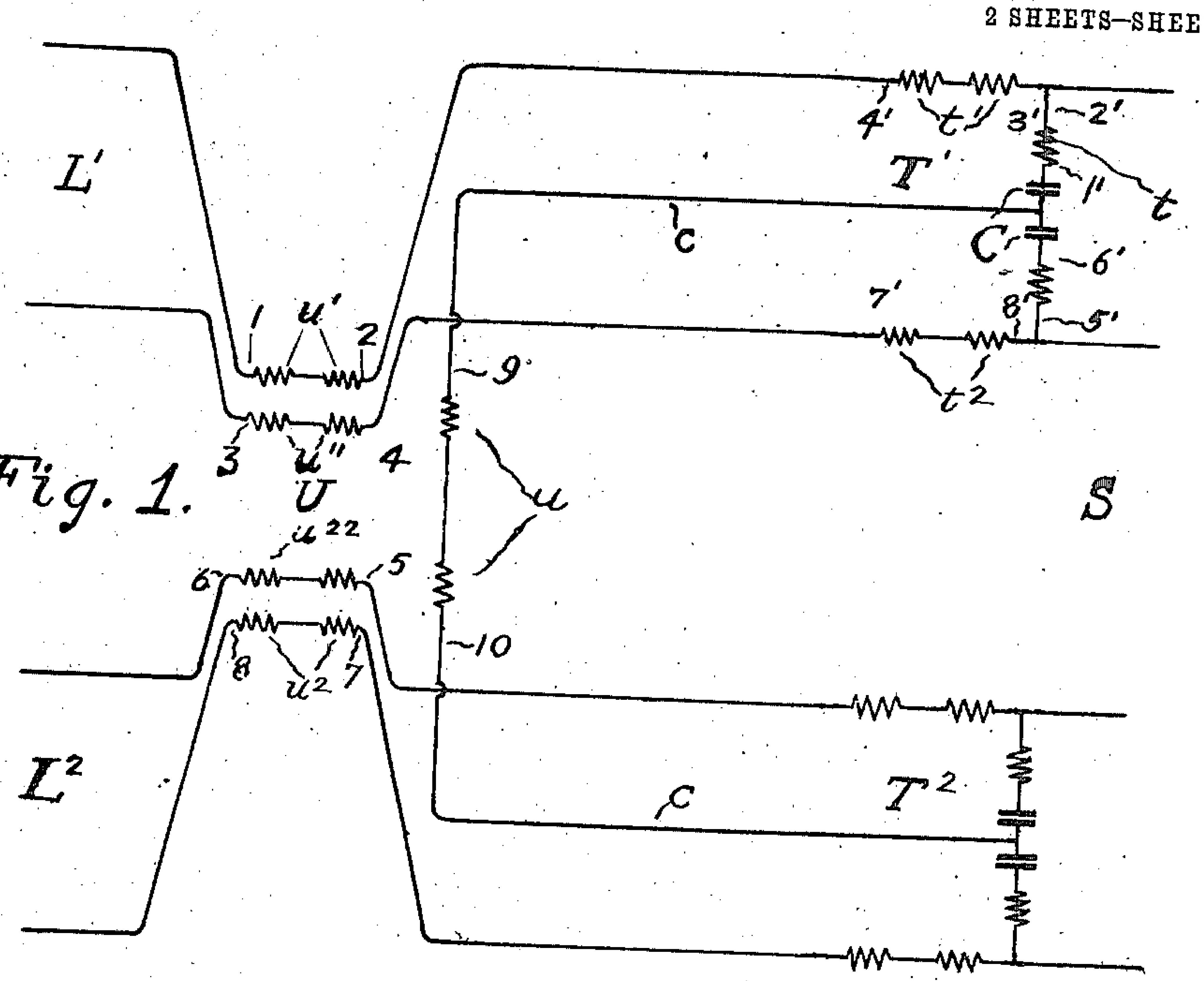
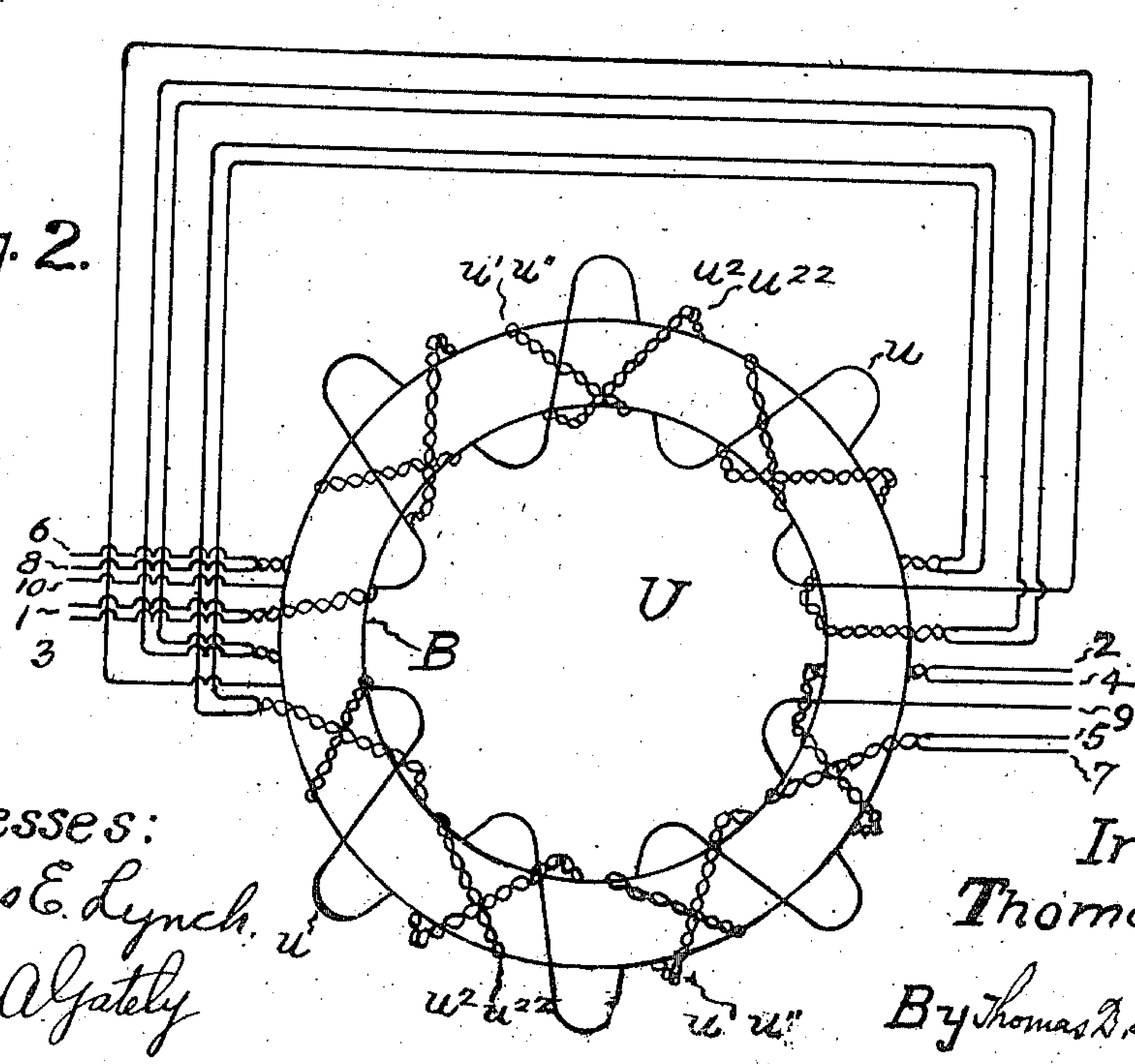


Fig. 1.

Fig. 2.



Witnesses:

James E. Lynch.

Joseph A. Gately

Inventor

Thomas Shaw

By Thomas D. Lockwood

Attorney.

T. SHAW.

MEANS FOR REDUCING REFLECTION LOSSES IN PHANTOM CIRCUITS.

APPLICATION FILED FEB. 28, 1913.

1,092,957.

Patented Apr. 14, 1914

2 SHEETS—SHEET 2.

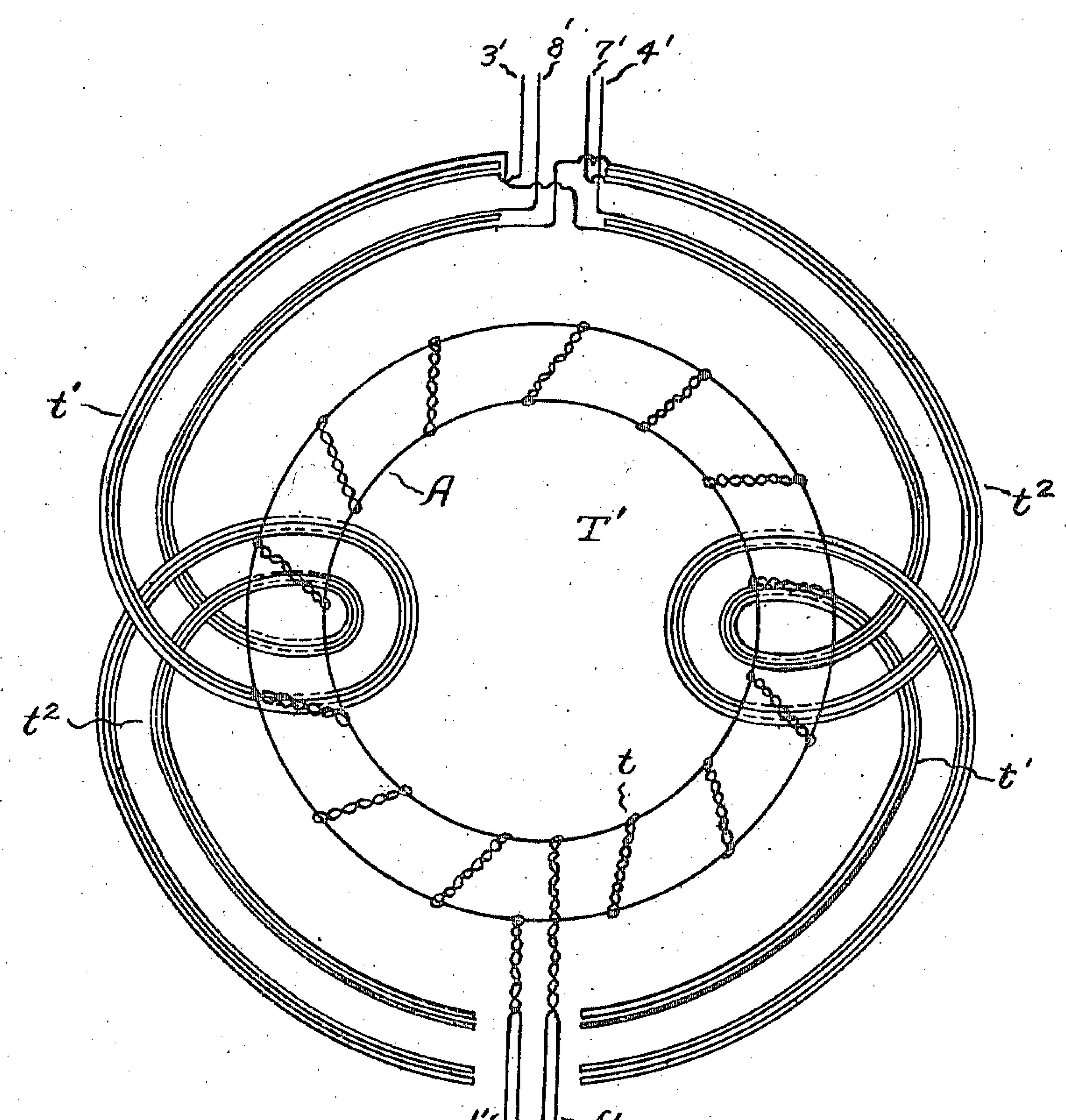


Fig. 3.

Witnesses:

James E. Lynch

Joseph A. Gately

Inventor

Thomas Shaw

By Thomas D. Lockwood.

Attorney.

UNITED STATES PATENT OFFICE.

THOMAS SHAW, OF HACKENSACK, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR REDUCING REFLECTION LOSSES IN PHANTOM CIRCUITS.

1,092,957. Specification of Letters Patent. Patented Apr. 14, 1914.

Application filed February 28, 1913. Serial No. 751,288.

To all whom it may concern:

Be it known that I, THOMAS SHAW, a citizen of the United States, residing at Hackensack, in the county of Bergen and State of New Jersey, have invented certain Improvements in Means for Reducing Reflection Losses in Phantom Circuits, of which the following is a specification.

To decrease the transmission losses caused by reflection at the junction of telephone lines of different impedance, a well known expedient consists in connecting these lines through a transformer adapted to step up or down, as the case may be, the impedance of one line to that of the other, this reflection reducing means being most effective when the impedance ratio of the transformer equals the ratio of impedances of the lines.

The present invention has for its object certain improvements in reflection reducing means of this character, it being especially applicable to that portion of a duplex telephone circuit termed a phantom circuit.

Because of the greater efficiency over the separate winding transformer, both with respect to copper and iron losses, of the type of device commonly known as an autotransformer, in which the windings are conductively connected, and because of its maintenance of the direct conductive continuity of the circuits, this device is useful in the present connection and with it my invention is more specifically concerned.

In the accompanying drawings, Figure 1 shows diagrammatically elements of a phantom circuit embodying my invention; Fig. 2 is a diagrammatic representation of an autotransformer for use in the phantom circuit; and Fig. 3 is a similar view of such a device adapted for application to the sides of the phantom.

Similar characters of reference designate like parts throughout.

In Fig. 1 is illustrated a portion of a phantom telephone circuit consisting of physical circuits L^1, L^2 with the conductors in parallel furnishing the sides of the phantom. For the purposes of this invention the physical circuits are considered to be in successive sections furnished by connected lines or portions of a single line, these sections presenting different impedances. The phantom would therefore have corresponding sections S, S^1 likewise different in impedance, S being the low and S^1 the high impedance section. At the junction of these sections reflection losses naturally occur. Included in the phantom circuit between the high and low impedance sections is a reflection reducing device preferably consisting of an autotransformer U. The windings u and u^1, u^{11}, u^2, u^{22} of this transformer may be looked upon as bearing a bridge and series relation to the phantom. u^1 and u^{11} are separately in series with the two conductors of the side circuit L^1, while u^2, u^{22} are similarly included in the conductors of L^2. Winding u is bridged by conductors c c between neutral points of the side circuits through a suitable combination of inductances and capacities, here illustrated as in the bridge windings of autotransformers T^1, T^2 belonging to the respective side circuits L^1, L^2. These devices T^1 and T^2, which may be identical in construction, will be later more fully described. The bridge winding u, of autotransformer U having connection with the side circuits, as above described, is entirely independent of operating current in the latter circuits and carries only operating current for the phantom, this being the difference between the current in the low and high impedance phantom sections. The current in said low impedance section does not traverse the series windings of the autotransformer U, through which flows the current in the high impedance section of the phantom, together with the operating current of the respective side circuits. It is desired that the transformer U shall produce its full reflection reducing effect upon the phantom circuit without substantial effect upon the side circuits. To this end the impedance of the bridge of the phantom, which consists mainly of the impedance of the winding u, should approximate the impedance of the phantom section S; and the impedance of the bridge plus that of the series windings u^1, u^{11} and u^2, u^{22} should correspond to the impedance section S^1. On the other hand, the side circuits should not be materially affected by the transformer U. The relation between the windings of the transformer should also be such as to minimize electromagnetic and electrostatic crosstalk between the phantom and its sides and between said sides.

Referring to Fig. 2, where, in addition to the letters indicating the windings as a whole, numerals are applied to designate the terminals, it will be seen that the series windings 1—2, 3—4 and 5—6, 7—8 corresponding to the side circuits L^1 and L^2, respectively, are each in the form of a twisted pair of conductors with each pair encircling the entire core B of the transformer, this core furnishing a closed magnetic circuit, it being preferably toroidal. Each series winding is arranged to balance as to resistance and inductance by being divided into sections each having an equal number of turns and occupying opposite halves of the core, with the sections on each half at different distances from the core; that is, one section of each pair is adjacent to the core and the other section outside a section of the companion pair. Over the series windings is placed the bridge winding 9—10, also enveloping the whole core and being in sections equally divided between the halves of said core. With the elements of the transformer in the relation shown, and considering first the phantom circuit, the series windings of each side circuit are in parallel, with the mutual inductance aiding the self inductances; and taken together the side circuit windings are in series with the mutual inductance between the pairs aiding the self inductances. Furthermore, the mutual inductance between the bridge winding and all the series windings increases the total inductance of the transformer for the phantom. The reflection reducing efficiency of the device may be expressed by the ratio of the impedance resulting from the series connection of the bridge winding 9—10 and the pairs 1—2, 3—4 and 5—6, 7—8 of series windings in inductive-aiding relation (it being remembered that each of these pairs of series windings considered separately is in parallel inductively aiding) to the impedance of the bridge winding. As the peculiar connection of the bridge winding prevents its influencing the side circuits, the only effect of the transformer upon the side circuit will be the series opposing impedance of the series windings, which will be equivalent to their direct current resistance only. The careful impedance balance between the various windings of the transformer practically eliminates electromagnetic crosstalk through it between the phantom and its sides. The twisting of both pairs of series windings and the alternating of the sections give perfect mutual symmetry with respect to the bridge winding, and of course one to the other. As to electrostatic crosstalk, the only direct admittances which can cause this and which are unsymmetrical are those between the outer layers of the series windings and inner layers of the bridge winding. This is comparatively unimportant. By properly proportioning the various windings of the transformer U an impedance ratio may be obtained adapting it to any particular values of impedance of the circuit sections. I will give the approximate data for a transformer such as hereinbefore described having the ratio of 3 to 1. The sections of the bridge winding may have 1,000 turns of conductor with a direct current resistance of 8 ohms; series windings 1—2, 3—4; 5—6, 7—8, each 365 turns with a direct current resistance of 4 ohms. For the phantom circuit there will be introduced by the transformer at a frequency of 800 cycles a series impedance of 124 ohms and 0.493 henry, a bridge impedance of 233 ohms and 0.925 henry and a mutual impedance of 163 ohms and 0.67 henry. For each side circuit there will be a series impedance of 8 ohms and 0.001 henry.

It is desirable to provide separate transformers for reducing the reflection losses in each side, these to be without substantial effect upon the phantom, in the same manner as the phantom transformer is independent of the sides. The transformers T^1, T^2, previously referred to as furnishing the inductances through which the bridge winding of the phantom is connected, are preferably thus organized, and one of these will now be described. This transformer, as T^1, comprises sets of windings t and t^1, t^2, which may conveniently be called the bridge and series windings, respectively. Winding t is bridged across the junction of the two circuit sections, while the series windings are connected to the extremities of the bridge in each of the conductors of the high impedance section. To allow common battery signaling, and for other purposes in which a metallic bridge is objectionable, the continuity of the bridge winding is broken by a balanced set of condensers C, C, from between which the connection c to the bridge winding of the phantom transformer U is led. These condensers serve also to break the metallic continuity of the phantom bridge. To practically confine the effect of the transformer T^1 to its side circuits its windings are arranged as follows, with the terminal connections as particularly indicated by numerals: A core A (Fig. 3) having a closed magnetic circuit, preferably of toroidal form, is shown. Extending about the entire core is the bridge winding t and series windings t^1 and t^2. The winding t is divided into sections between which condensers C, C are inserted, these sections having terminals 1′—2′ and 5′—6′. The series winding t^1 of one of the side conductors has terminals 3′—4′, and the series winding t^2 of the other conductor terminals 7′—8′. Each series winding may be divided into two sections, all the sections having the same number of turns. Either the bridge or series windings preferably consists of a twisted pair of conductors. In the present instance the bridge winding is thus arranged and is situated next to the core. Each series winding has its sections upon opposite halves of the core, the sections of the same winding being at different distances therefrom. As these windings are distributed and connected they are in series with respect to current in the side circuit with their mutual inductance aiding the self inductances; and the impedance ratio, which controls the reflection reducing efficiency of the device, will be the ratio of the impedance of windings 4′—3′, 2′—1′, 6′—5′ and 8′—7′ in series-aiding to that of the bridge winding sections 2′—1′, 6′—5′ similarly related. The effect of the transformer upon the phantom circuit will be to include therein impedance equal to the series windings 4′—3′, 7′—8′ in parallel with their mutual inductance opposing their self inductance plus the bridge winding sections 2′—1′, 5′—6′ also in parallel-opposing. Transformers T^1, T^2, above described for reducing reflection losses in the side circuits, are not herein specifically claimed as they form the subject matter of and are claimed in my copending application Serial No. 751,287, filed February 28, 1913.

I claim:

1. The combination with physical circuits associated to furnish a phantom circuit, said phantom circuit comprising successive sections of different impedance, of a reflection reducing transformer situated at the junction of the phantom sections, said transformer including a winding traversed by current in the phantom circuit only.

2. The combination with physical circuits associated to furnish a phantom circuit, said phantom circuit comprising successive sections of different impedance, of a reflection reducing transformer situated at the junction of the phantom sections, said transformer including a winding traversed by current in the phantom circuit only, and other windings traversed by current in the physical circuits.

3. The combination with physical circuits associated to furnish a phantom circuit, said phantom circuit comprising successive sections of different impedance, of a reflection reducing transformer situated at the junction of the phantom sections, said transformer including a winding traversed by current in the phantom circuit only, and other windings traversed by current in both the phantom and physical circuits.

4. The combination with physical circuits associated to furnish a phantom circuit, said phantom circuit comprising successive sections of different impedance, of a reflection reducing transformer situated at the junction of the phantom sections, the relation between the windings of said transformer tending to minimize its effect on the physical circuits

5. The combination with two physical circuits associated to furnish a phantom circuit, of a transformer associated with the phantom circuit, said transformer including windings in said physical circuits and a winding connected between the conductors of each physical circuit at neutral points in said circuits.

6. The combination with two physical circuits associated to furnish a phantom circuit, of a transformer having a winding in each conductor of each of the physical circuits, and a winding connected between the conductors of each of the physical circuits in parallel.

7. The combination with two physical circuits associated to furnish a phantom circuit, of a reflection reducing transformer associated with the phantom circuit, said transformer including a winding connected between the conductors of each physical circuit at neutral points in said circuits, and a winding in each of the physical circuits.

8. The combination with two physical circuits associated to furnish a phantom circuit, of a transformer having a winding in each conductor of each of the physical circuits, and a winding connected between the conductors of each of the physical circuits in parallel, the mutual inductance between the windings in the physical circuits aiding the self inductances thereof.

9. The combination with two physical circuits associated to furnish a phantom circuit, of a transformer having a winding in each conductor of each of the physical circuits, and a winding connected between the conductors of each of the physical circuits in parallel, the windings in the conductors of each of the physical circuits being in parallel with their mutual inductance aiding their self inductances for current in the phantom circuit.

10. The combination with two physical circuits associated to furnish a phantom circuit, of a transformer having a winding in each conductor of each of the physical circuits, and a winding connected between the conductors of each of the physical circuits, the windings in the conductors of the physical circuits being in series with their mutual inductance opposing their self inductances for the operating current of said physical circuits.

11. The combination with two physical circuits associated to furnish a phantom circuit, of a transformer having a series winding in each conductor of each of the physical circuits, and a bridge winding connected between the conductors of the physical circuits, the series windings being in parallel with their mutual inductance aiding their self inductances for current in the phantom circuit, the mutual inductance between the bridge winding and the series windings add-

ing to the total inductance of the windings for said phantom circuit.

12. The combination with two physical circuits associated to furnish a phantom circuit, of a reflection reducing transformer for the phantom circuit having a bridge winding connected between the physical circuits, and series windings in the conductors of the physical circuits.

13. The combination with two physical circuits associated to furnish a phantom circuit comprising successive sections, of a transformer situated at the junction of the phantom sections and having a core, and windings on the core consisting of series windings in conductors of the physical circuits, and a bridge winding connected between the conductors of the physical circuits, one of the windings being in the form of a twisted pair.

14. The combination with two physical circuits associated to furnish a phantom circuit comprising successive sections, of a transformer situated at the junction of the phantom sections and having a core, and windings on the core consisting of a series winding for each conductor of the physical circuits, and a bridge winding connected between the conductors of the physical circuits in parallel, the series windings for each physical circuit being in the form of a twisted pair.

15. The combination with two physical circuits associated to furnish a phantom circuit comprising successive sections, of a transformer situated at the junction of the phantom sections and having a core, and windings on the core consisting of a series winding for each conductor of the physical circuits, and a bridge winding connected between the conductors of the physical circuits in parallel, the series windings of each physical circuit being in sections situated on different portions of the core.

16. The combination with two physical circuits associated to furnish a phantom circuit comprising successive sections, of a transformer situated at the junction of the phantom sections and having a core, and windings on the core consisting of a series winding for each conductor of the physical circuits, and a bridge winding connected between the conductors of the physical circuits in parallel, the series windings of each physical circuit being in the form of a twisted pair arranged in sections upon different portions of the core.

17. The combination with two physical circuits associated to furnish a phantom circuit comprising successive sections, of a transformer situated at the junction of the phantom sections and having a core, and windings on the core consisting of a series winding for each conductor of the physical circuits, and a bridge winding connected between the conductors of the physical circuits in parallel, the series windings of each physical circuit being in sections situated on different portions of the core, the sections of the same winding being at different distances from the core.

18. The combination with two physical circuits associated to furnish a phantom circuit comprising successive sections, of a transformer situated at the junction of the phantom sections and having a core, and windings on the core consisting of a series winding for each conductor of the physical circuits, and a bridge winding connected between the conductors of the physical circuits in parallel, the series windings for each physical circuit being in the form of a twisted pair and the bridge winding being a single conductor located outside the series windings.

19. Two physical circuits associated to furnish a phantom circuit, the physical and phantom circuits comprising sections of different impedance, and a separate reflection reducing transformer situated at the junction of the sections of each physical circuit and of the phantom circuit.

20. Two physical circuits associated to furnish a phantom circuit, the physical and phantom circuits comprising sections of different impedance, a separate reflection reducing transformer situated at the junction of the sections of each physical circuit and of the phantom circuit, and means forming a part of each transformer for substantially confining the reflection reducing effect of each transformer to its individual circuit.

21. Two physical circuits associated to furnish a phantom circuit, the physical and phantom circuits comprising sections of different impedance, a separate reflection reducing transformer situated at the junction of the sections of each physical circuit and of the phantom circuit, the windings of each transformer being inductively arranged to substantially confine the effect of each transformer to its individual circuit.

22. Two physical circuits associated to furnish a phantom circuit, the physical and phantom circuits comprising sections of different impedance, a separate reflection reducing transformer situated at the junction of the sections of each physical circuit and of the phantom circuit, each transformer having series windings and a bridge winding, the bridge winding of the transformer in the phantom circuit being connected to the bridge windings of both transformers in the physical circuits.

23. Two physical circuits associated to furnish a phantom circuit, the physical and phantom circuits comprising sections of different impedance, a separate reflection reducing transformer situated at the junction of the sections of each physical circuit and

of the phantom circuit, each transformer having series windings and a bridge winding, the bridge winding of the transformer in the phantom circuit being connected to the bridge windings of both transformers in the physical circuits at neutral points therein.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses, this eighteenth day of February, 1913.

THOMAS SHAW.

Witnesses:
ELAM MILLER,
LLOYD ESPENSCHIED.