G. A. CAMPBELL & T. SHAW.

LOADED PHANTOM CIRCUIT.

APPLICATION FILED FEB. 12, 1910.

980,921.

Patented Jan. 10, 1911.

3 SHEETS—SHEET 1.

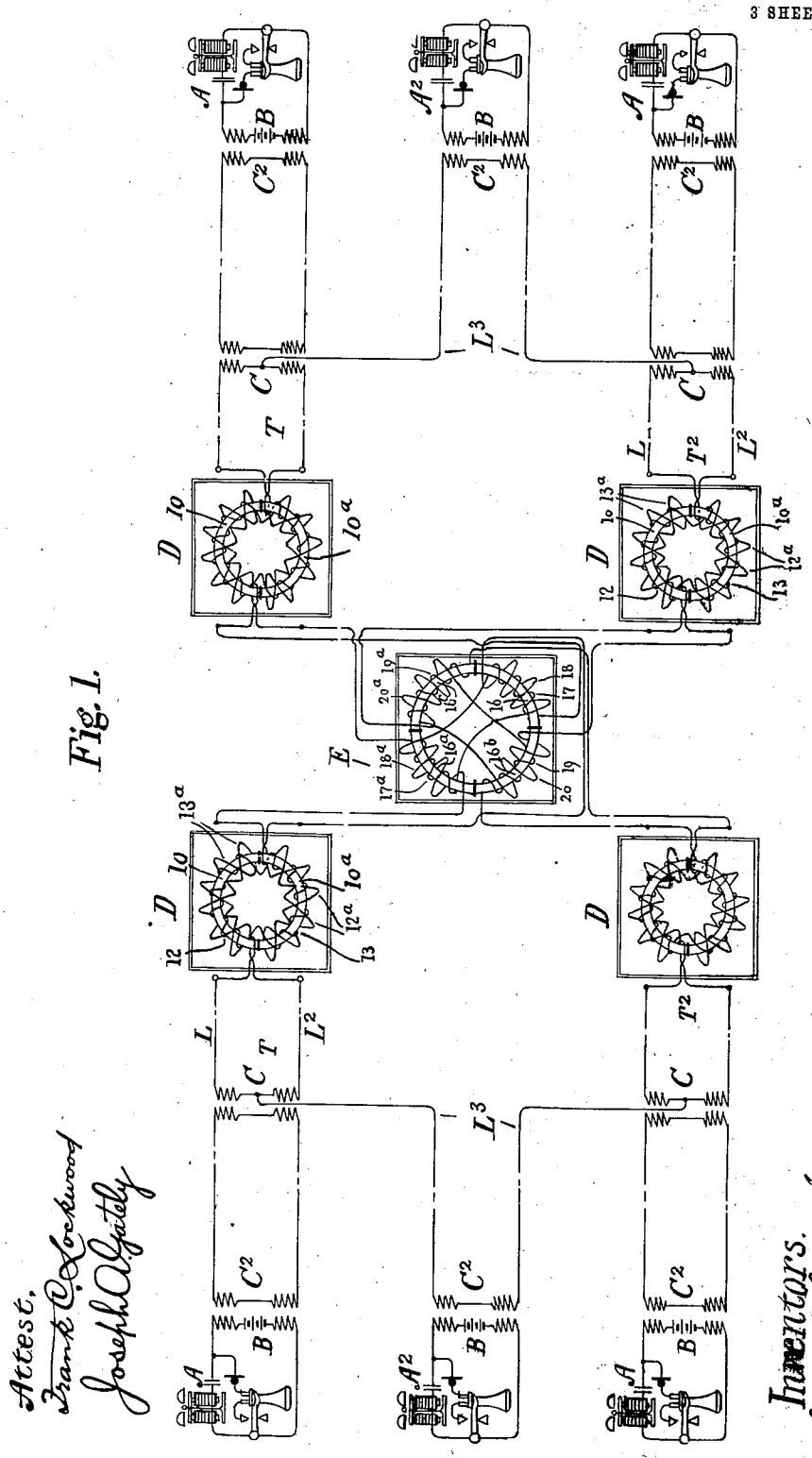

Fig. 1.

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3 SHEETS—SHEET 2.

Fig. 2.

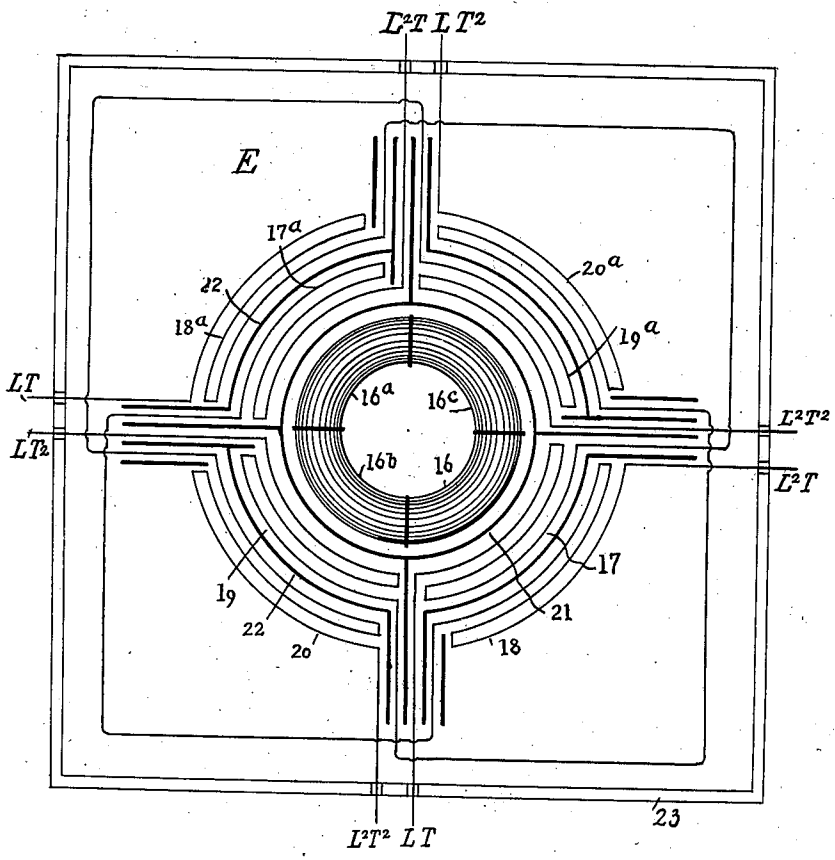
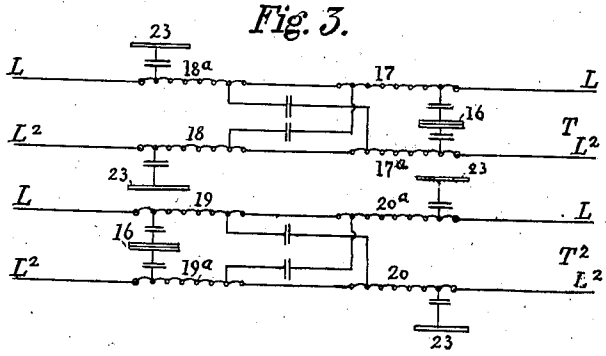


Fig. 3.



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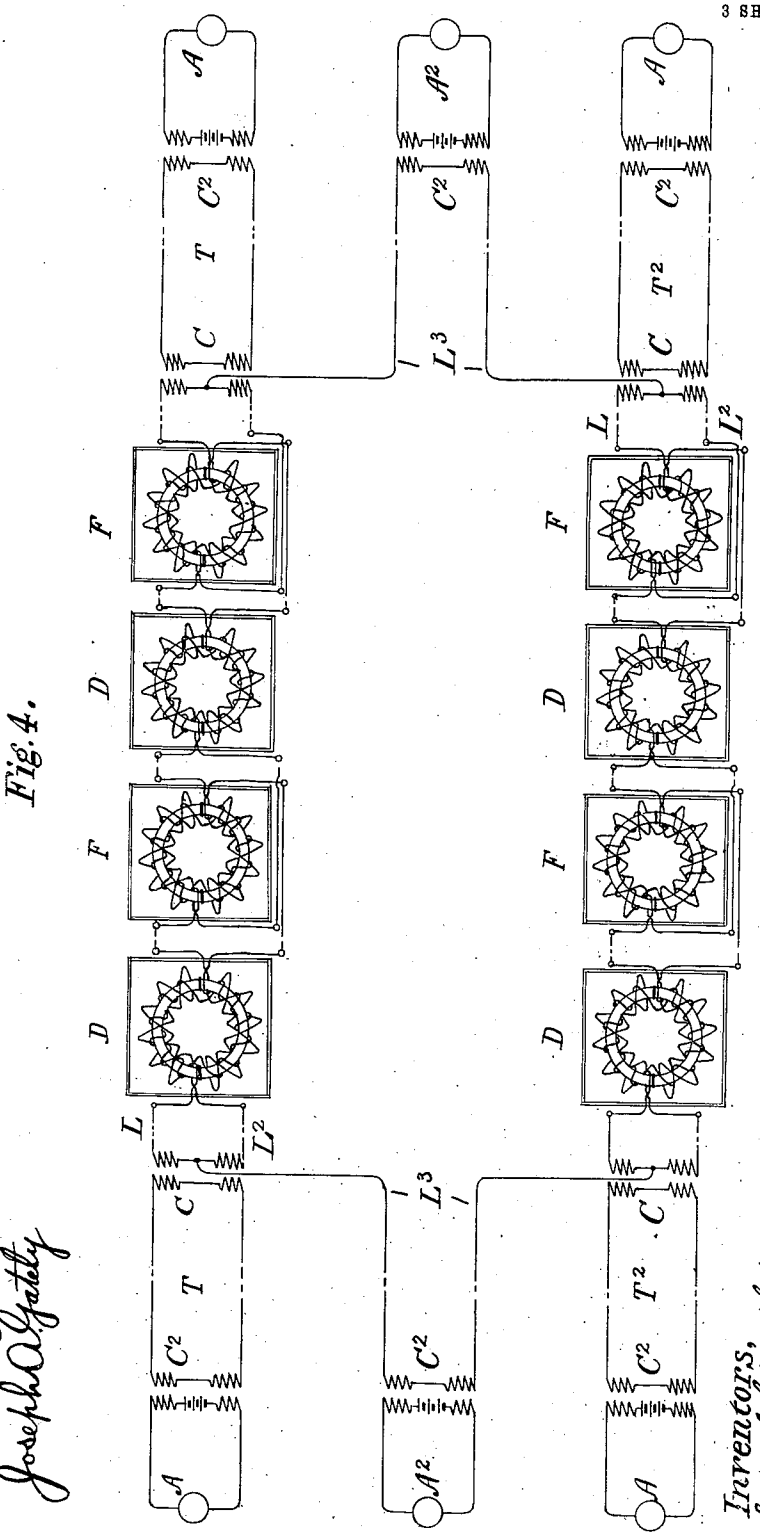

Fig. 4.

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UNITED STATES PATENT OFFICE.

GEORGE A. CAMPBELL, OF BROOKLYN, NEW YORK, AND THOMAS SHAW, OF HACKENSACK, NEW JERSEY, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

LOADED PHANTOM-CIRCUIT.

980,921. Specification of Letters Patent. **Patented Jan. 10, 1911.**

Application filed February 12, 1910. Serial No. 543,543.

To all whom it may concern:

Be it known that we, GEORGE A. CAMPBELL and THOMAS SHAW, residing at Brooklyn and at Hackensack, respectively, in the counties of Kings and Bergen, respectively, and States of New York and New Jersey, respectively, have invented certain Improvements in Loaded Phantom-Circuits, of which the following is a specification.

In dealing with lines for the transmission of electrical signals, as telephone or telegraph lines, loaded upon the Pupin system, that is, with lumped inductances distributed throughout the circuit and serving to diminish the attenuation of the signaling waves or impulses, it obviously may be desirable to combine two or more transmitting circuits to form a third, or, as it is termed in telephony, "phantom" circuit. This is commonly effected by employing in parallel the two limbs of a metallic circuit to furnish each side of the phantom, the impulses generated in either of the original or physical circuits and in the combined or phantom circuit being caused to act only upon their respective receiving instruments by means of a differential repeating coil in a manner well known. While the loading coils for the physical circuits may be so organized that they provide therein the necessary inductance without greatly increasing the effective resistance or other working characteristics of the phantom, they are also without appreciable effect upon the inductance of said phantom. Therefore, if it is desired to also load the latter circuit other means must be resorted to, and to furnish such means is the purpose of this invention.

In the accompanying drawings, in which similar characters of reference are applied to like parts throughout the several views: Figure 1 is a diagram showing phantomed loaded circuits, with the phantom itself loaded in accordance with our invention; Fig. 2 is an enlarged diagram representing one of the phantom loading coils; Fig. 3 illustrates diagrammatically the distribution of admittances in a coil; and Fig. 4 is a view similar to Fig. 1 illustrating a modification of the circuit.

Referring particularly to Fig. 1, the characters L and L^2 designate, respectively, the opposite limbs of two metallic circuit telephone lines T and T^2, each having terminal stations A, A. Near the extremities of both lines are the usual simplex repeating coils C, to the center of one winding of each of which is joined a conductor L^3 which continues to stations A^2 the phantom circuit furnished by the pairs of conductors L, L^2 in parallel. Current from batteries B is supplied to the physical and phantom circuits through repeating coils C^2. In both of the lines T, T^2 are included loading coils D, there being a sufficient number to introduce the required amount of inductance. Each coil may comprise a ring-shaped core of iron about which are windings for both sides of the line, each of said windings consisting of two sections of conductor which together encircle the entire core, there being a section of each winding upon each half core 10 10^a.

Referring to either of the physical circuits, upon the core section 10 is a winding section 12 for the conductor L of the line, and over the core section 10^a is a winding section 12^a, while the line conductor L^2 includes opposite windings 13 and 13^a. To render the coil symmetrical in the relation of its windings to one another and to the core, the sections are of approximately equal impedance and those included in the same conductor are placed alternately directly about the core and outside the sections of the companion winding, The windings are of such length and direction, and the sections are so connected, that the desired inductance is introduced into each side of the physical circuit, the effective resistance being about the same as in the standard loading coil, and it will be evident that a very perfect balance may be maintained between the windings. When the windings are in parallel and exerting an opposing influence there is but little energy wasted in magnetic leakage, and the effective resistance imposed upon the phantom is slight. The inductance of the opposing windings is negligible, therefore the phantom circuit is not loaded.

Coöperating with both the physical circuits are loading coils E for the phantom, but one of which is here illustrated, their number being controlled by the inductance required to satisfactorily diminish the attenuation of current waves therein. Each

coil has a core preferably in the form of a ring consisting of a bundle of iron wire furnishing quarter sections 16, 16^a, 16^b and 16^c, which are ordinarily parts of a continuous ring, in which case the term "section" would refer merely to the portion of the core upon which the windings are placed. In this, the preferred form of our invention, the core is common to windings included in the conductors L and L^2 of both physical circuits T and T^2 with each line pair localized upon diametrically opposite quarters of the core. The winding of each conductor is divided into sections, there being upon the core section 16 winding sections 17 and 18 belonging to the conductors L and L^2, respectively, of the line T, while upon the core section 16^a are winding sections 17^a and 18^a of conductors L^2 and L of said line. Similarly, over the core sections 16^b and 16^c are winding sections 19, 20 and 20^a and 19^a of conductors L and L^2, respectively, of the line T^2. These coil sections are so wound and connected that when they are in parallel, as is the case in either side of the phantom circuit, their mutual inductance increases their self inductance; and with these two parallel sides joined in series to complete the phantom, their mutual inductances are also added, these together giving the loading effect. This should be secured without the introduction of material transmission losses into the physical circuits and with comparative freedom from cross talk between the phantom and physical circuits and between such component circuits. The winding sections are therefore made of equal impedance and are symmetrically arranged upon the core sections. This may be seen most clearly in Fig. 2 of the drawings, where, for convenience in illustration, the windings appear outside the core instead of surrounding and threaded through it, as is actually the case and as is represented in Fig. 1. It will be seen that winding sections 17 and 17^a encircle insulating material 21 covering the quarter sections 16 and 16^a of the core, with winding sections 19 and 19^a similarly placed upon the core sections 16^b and 16^c; while the other winding sections in each case surround a section included in the associated conductor of the line pair and being separated therefrom by insulation 22. Therefore, the windings belonging to the conductors of each line are concentrically arranged throughout, with their sections alternating in regard to their distance from the core. In each pair of concentric sections the current for the physical circuits through each pair of conductors L, L^2 in series travels about the core in opposite directions, and, as the number of turns and the impedance of these sections are substantially the same, the magnetomotive forces which they produce will tend to neutralize one another. As a result of this, there will be little leakage of lines of force into such unlaminated metal objects as the case 23, which customarily incloses the coils, and only slight energy loss appearing as effective resistance in the physical circuits. The only loading effect which the phantom coils will have upon the physical circuits will be what may arise from these trifling losses, the mutual inductance failing to exactly balance the self inductance.

Considering the passage of current for the phantom circuit through the pairs of conductors L, L^2 in parallel, this will be in the same direction about the core in all the winding sections; and, since these sections cover the entire core and are symmetrical as to impedance and position, there will be practically no external field or leakage from the coils and no expenditure of energy thereby. In addition to the substantial equality and symmetry between the impedances of the winding sections, both with respect to the windings forming each side of the phantom and the windings not associated with the same side of the phantom, the sections are so arranged that the outer layers, or those in proximity to other sections and to the core and case, are at substantially the same potential as similarly located sections to and from which there might be a transfer of current by electrostatic induction. This symmetrical distribution of the direct admittances is clearly shown in Fig. 3 of the drawings, taken in connection with Fig. 2, and requires no further explanation. As a consequence of all these features of symmetry and balance the crosstalk between the phantom and its physical circuits and between such physical circuits is negligible.

In a system loaded in accordance with this invention by coils having the usual cores, and with each line winding consisting of about 163 inner turns of No. 17 B. & S. and about 163 outer turns of No. 16 B. & S. double cotton-covered copper conductor through which an alternating current of 800 microamperes at 800 periods per second flows, each coil was found to add to the phantom an inductance of 0.102 of a henry and effective resistance of 3.35 ohms, while the two physical circuits each received inductances of 718 microhenries and 1.72 ohms resistance, the latter value being 0.08 of an ohm more than the corresponding direct current resistance.

Although the invention has been described in connection with a phantom circuit made up of loaded lines, it will be evident that it is equally applicable to lines without loading coils.

In Fig. 4 is illustrated a modification of the invention. Here the coils D of each of the physical circuits may be as hereinbefore

set forth, but in the loading coils F for the phantom, the four windings for the two sides, instead of being upon a common core as in the coil E, are separated, the windings for each line pair having an individual core. Similarly to the coils D, and for the purpose of reducing the magnetic leakage and consequent transmission losses, the winding for each conductor is preferably in sections and surrounds the entire core, being situated alternately inside and outside the other winding sections. In this case, however, the sections are so joined as to add the mutual inductances of the windings to the self-inductance for the currents in the phantom passing in the same direction through the parallel line conductors. This may be accomplished by reversing the connections of the winding for one line conductor. Though this arrangement provides for the desired loading of the phantom, it increases the number of coils which it is necessary to use, introduces an additional resistance into the physical circuits and is liable to cause cross talk.

We claim:

1. In a system for the transmission of electrical signals, a plurality of transmitting circuits combined to form opposite sides of another or phantom circuit, and inductances included in each side of the phantom circuit and serving to diminish the attenuation of the signaling impulses therein.

2. In a system for the transmission of electrical signals, a plurality of transmitting circuits combined to form opposite sides of another or phantom circuit, loading coils included in the first-named circuits, and means for loading the phantom circuit independently of the loading coils of the component circuits.

3. Two telephone lines combined to furnish by the conductors of each in parallel opposite sides of a phantom circuit, and an inductance in each conductor of both lines, each inductance being associated in inductive relation to the inductance in the companion conductor of the line and being so connected that their mutual effect is added to the self-inductance.

4. In an electrical signaling system, two line circuits associated to furnish a third or phantom circuit, and a loading coil for the phantom circuit having a winding included in each line conductor and a core common to all of said windings.

5. In an electrical signaling system, two line circuits associated to furnish a third or phantom circuit, and a loading coil for the phantom circuit having a winding included in each line conductor and a core common to all of said windings, the windings for the two lines being upon different sections of the core.

6. The combination with two telephone lines, of means for forming a phantom circuit therefrom, and a loading coil for the phantom circuit comprising a winding included in each side of the component lines, each of said windings being divided into sections situated concentrically with respect to the sections of the other winding belonging to the same line.

7. The combination with two telephone lines, of means for forming a phantom circuit therefrom, and a loading coil for the phantom circuit comprising a winding included in each side of both component lines, each of said windings being divided into sections which are situated concentrically with respect to the sections of the other winding belonging to the same line and alternately inside and outside the same.

8. In an electrical signaling system, two line circuits associated to furnish a third or phantom circuit, and a loading coil for the phantom circuit having a winding included in each line conductor and a core common to all the windings, the windings for each line being on diametrically opposite quarter sections of the core.

9. In a telephone system, two line circuits associated to furnish a phantom circuit, and a loading coil for the phantom circuit comprising sectional windings included in both component lines, the admittances between each sectional winding and the other elements of the coil being symmetrically distributed.

In testimony whereof, we have signed our names to this specification in the presence of two subscribing witnesses, this twenty eighth day of January, 1910.

GEORGE A. CAMPBELL.
THOMAS SHAW.

Witnesses:
W. M. GOULD,
FRANK B. JEWETT.