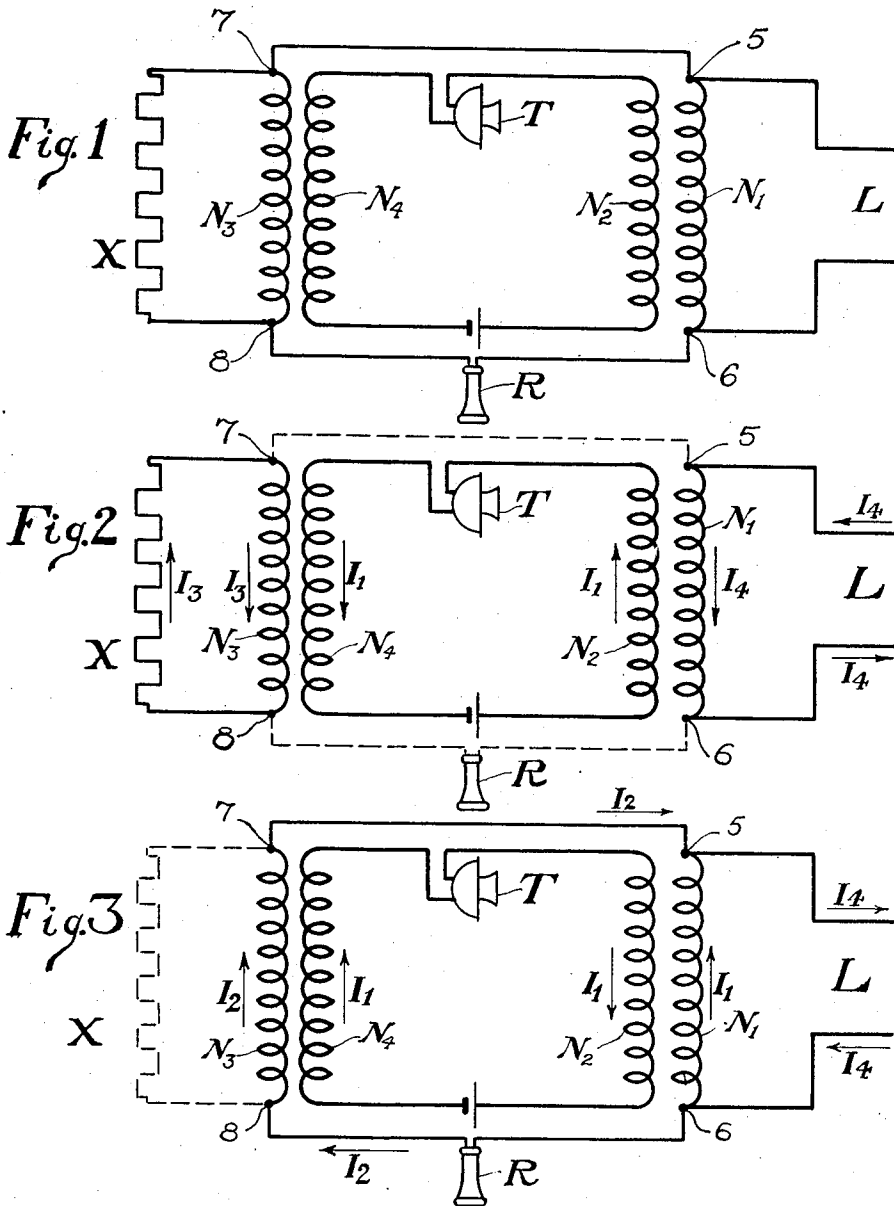


1,347,849.

Patented July 27, 1920.
 3 SHEETS—SHEET 1.



WITNESSES:

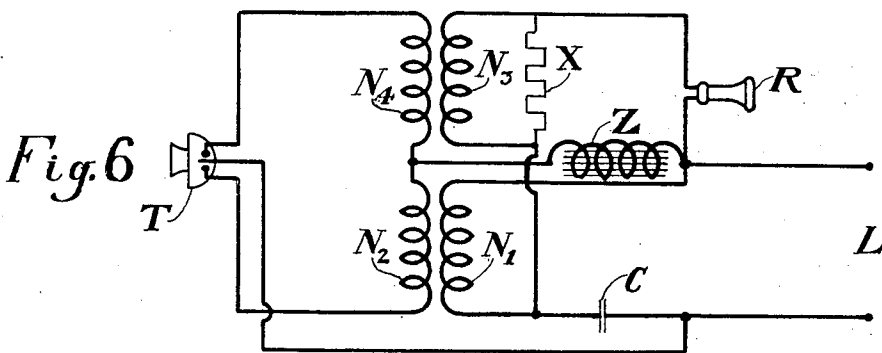
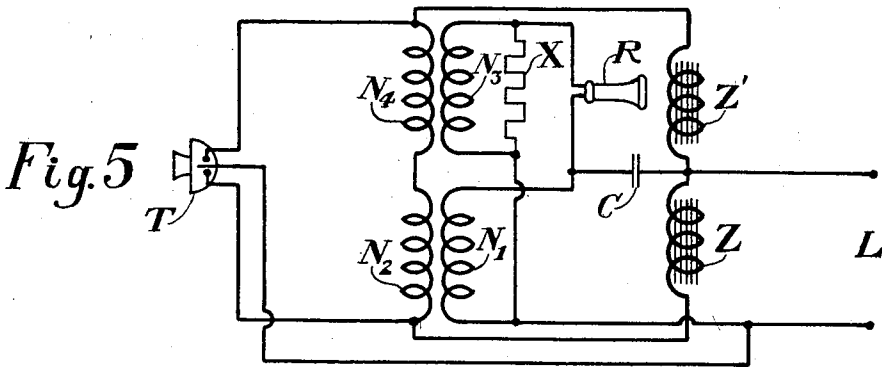
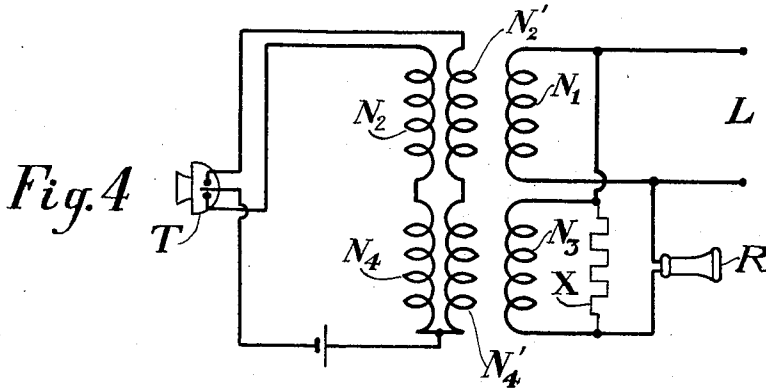
H. J. Barnar
C. B. McCoy

INVENTOR

Paul J. Hackett

1,347,849.

Patented July 27, 1920.
 3 SHEETS—SHEET 2.



WITNESSES:

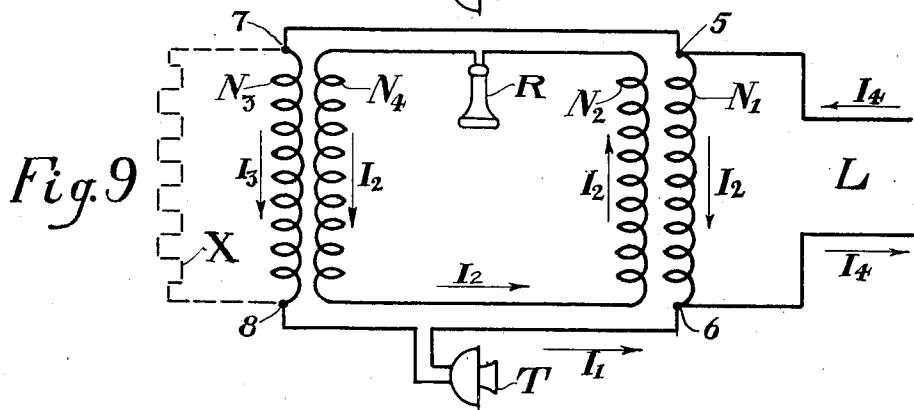
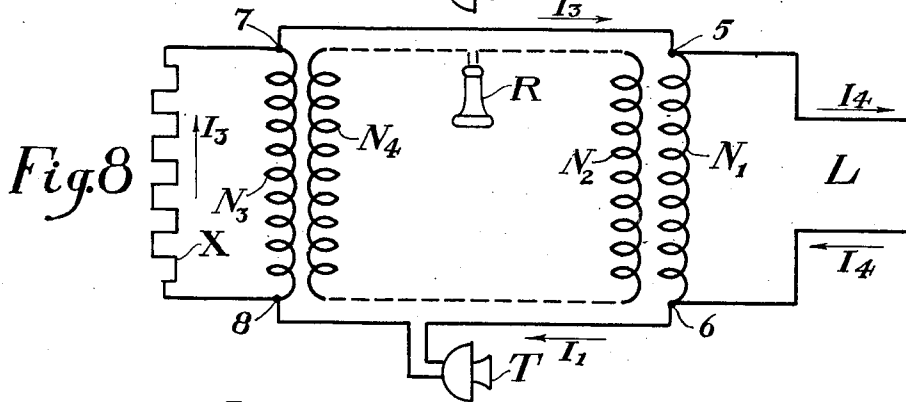
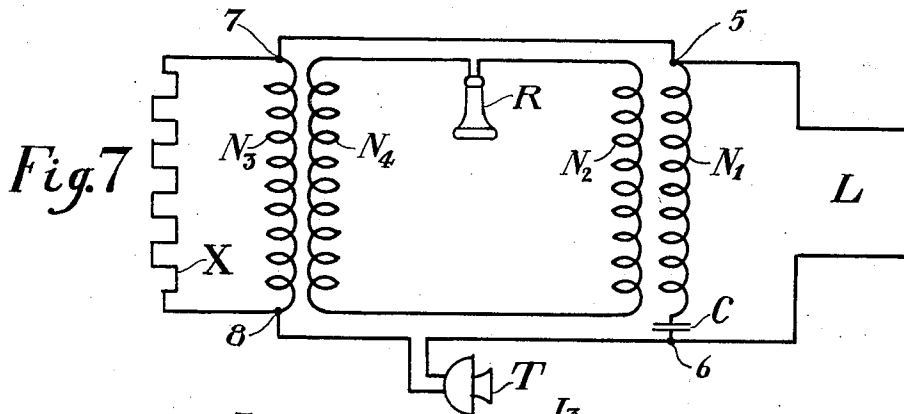
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INVENTOR

Paul J. Hackett

1,347,849.

Patented July 27, 1920.
 3 SHEETS—SHEET 3.



WITNESSES:
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INVENTOR
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 BY

ATTORNEY

UNITED STATES PATENT OFFICE.

PAUL J. HACKETT, OF SEATTLE, WASHINGTON, ASSIGNOR TO UNIVERSAL HIGH-POWER TELEPHONE CO., OF SEATTLE, WASHINGTON.

SIGNALING-CIRCUIT.

1,347,849.

Specification of Letters Patent.

Patented July 27, 1920.

Application filed June 21, 1919. Serial No. 305,755.

To all whom it may concern:

Be it known that I, PAUL J. HACKETT, a citizen of the United States, residing at Seattle, in the county of King and State of Washington, have invented a certain new and useful Improvement in Signaling-Circuits, of which the following is a full, clear, concise, and exact description.

This invention relates to the circuit arrangement of a telephone substation, and more particularly to telephone substations in combination with a telephone line over which two-way communication is to be established.

The object of this invention is to provide a circuit arrangement of the substation apparatus in a single line circuit two-way communication system such that each substation will be free from side tone, and, will also give a maximum ratio of received to transmitted energy consistent with the requirements necessary to secure freedom from side tone.

In order to attain the objects of this invention several requirements must be satisfied. In a single line circuit two-way communicating system, it is impossible to secure freedom from side tone without the use of an auxiliary resistance element at each substation in addition to the regular equipment of a transmitter, a receiver, and induction coils. In eliminating the side tone while transmitting, the auxiliary resistance receives the energy which would otherwise go to the receiver. One requirement therefore, is: (1) The receiver and transmitter must be conjugate, that is the receiver must not be affected by energy originating in the transmitter of the same substation. Other requirements are: (2) for a line of given impedance the energy delivered by the transmitter must be a maximum; (3) the energy delivered by the line to the substation must be a maximum; (4) the line and auxiliary resistance must be conjugate in order that none of the energy delivered by the line to the substation shall be wasted in the resistance while receiving.

The substation of my invention is provided with a transmitter, a receiver, an auxiliary resistance and necessary transformers to so connect and relate the component elements to each other and to the line that the above mentioned requirements are fulfilled.

The specific embodiment of my invention

is illustrated in the accompanying drawings in which Figure 1 is a diagram of the fundamental arrangement of the substation apparatus, the remaining drawings illustrating modifications of Fig. 1. Figs. 2 and 3 are diagrams showing the direction of current flow in the substation of Fig. 1 while transmitting and receiving respectively. Fig. 4, shows the substation of my invention adapted for the use of a differential transmitter. Figs. 5 and 6 show the substation of my invention adapted for use in common battery systems using a differential transmitter. The use of a differential transmitter in common battery systems makes necessary the impedance coils ZZ' and Z . Fig. 7 is a diagram illustrating a modification of the substation of Fig. 1 in that the transmitter and receiver are inter-changed so as to be suited for common battery systems using a simple transmitter. Condenser C may be placed in series with a winding N_1 to prevent the flow of direct current through this path. Figs. 8 and 9 are diagrams illustrating the flow of current in the substation of Fig. 7 while transmitting and receiving respectively.

Referring to Fig. 1, L is a line connected to a substation comprising a transmitter T , a receiver R , an auxiliary resistance X , and two induction coils having two windings each N_1, N_2 and N_3, N_4 respectively. The receiver R , and auxiliary resistance X , are serially connected across the line L by terminals 5, 6, 7, and 8. Winding N_1 of an induction coil is in bridge of line L , and winding N_3 of the other induction coil is in bridge of resistance X . The remaining windings N_2 and N_4 of the induction coils, and the transmitter T , form a separate serial circuit being inductively associated with the other elements by means of the induction coils.

The operation of the substation during transmission is shown in Fig. 2. Upon speaking into the transmitter the action is equivalent to generating an alternating voltage in the transmitter. Considering, then, that the transmitter is a source of alternating current, a current I_1 will flow in the transmitter circuit through windings N_2, N_4 inducing currents I_2 and I_3 in the line and auxiliary resistance circuits respectively. The direction of current flow is indicated by the arrows. The arrows also indicate the direction of induced voltages in windings

N_1 and N_3 which are included in the receiver circuit 8756. The substation being properly designed, no current will flow through the receiver circuit since the voltages acting in this circuit are equal and opposite. The current flow during reception is shown in Fig. 3 and the action is as follows: An alternating voltage applied to the line will supply a line current I_4 to the substation, this current dividing at terminal 6, a part I_2 flowing through the receiver R, winding N_3 , and back to the line through terminal 5; another part I_1 flowing through winding N_1 . Current I_1 in winding N_1 induces a current I_1 in the transmitter circuit. The substation being properly designed, the magneto-motive-force of winding N_3 is equal and opposite to the magneto-motive-force of winding N_4 , consequently, neglecting the resistance drop in winding N_3 , there will be no voltage drop across winding N_3 and no current will flow through the auxiliary resistance X.

The necessary design formulæ for the proper proportioning of the various elements and transformer ratios to meet the above requirements may be derived as follows:

Let the number of turns of windings N_1 , N_2 , N_3 and N_4 be denoted by n_1 , n_2 , n_3 and n_4 respectively; and let the current and resistance of the transmitter, receiver, auxiliary resistance and line be denoted by I_1 , I_2 , I_3 , I_4 and R_1 , R_2 , R_3 , R_4 respectively. In deriving these formulæ the transformer windings will be assumed to have negligible resistance and to be closely coupled. The line impedance and the impedance of the component elements will also be assumed to be pure resistance, since any reactance effect may be neutralized if desired. The first requirement is that the transmitter and receiver must be conjugate, that is no current must flow in the receiver circuit while transmitting. Referring to Fig. 2, assume, then, that no current flows through the receiver, and the following relations must be satisfied,

$$\begin{aligned} I_2 &= 0 \\ \text{and} \quad I_3 R_3 &= I_4 R_4 \\ \text{or} \quad R_3 &= \frac{I_4 R_4}{I_3} \quad (1) \end{aligned}$$

$$\text{also} \quad I_3 n_3 = I_1 n_4 \quad (2)$$

$$\text{and} \quad I_4 n_1 = I_1 n_2 \quad (3)$$

dividing (3) by (2)

$$\frac{I_4 n_1}{I_3 n_3} = \frac{n_2}{n_4}$$

$$\text{or} \quad \frac{I_4}{I_3} = \frac{n_2 n_3}{n_1 n_4}$$

$$\text{substituting in (1)} \quad R_3 = R_4 \left(\frac{n_2 n_3}{n_1 n_4} \right) \quad (4)$$

Another requirement is that the auxiliary resistance must be conjugate to the line

while receiving. Referring to Fig. 3, the following relations must be true in order for no current to flow in the auxiliary resistance while receiving:

$$I_2 n_3 = I_1 n_4 \quad 70$$

$$\text{and} \quad I_1 R_1 \left(\frac{n_1}{n_2} \right) = I_2 R_2$$

$$\text{whence} \quad R_1 = R_2 \left(\frac{n_2 n_4}{n_1 n_3} \right) \quad (5) \quad 75$$

Another requirement is that the line must supply maximum energy to the substation. It is a fundamental principle that the resistance of the terminal apparatus connected to a line must be equal to the resistance of the line for maximum delivery of energy, neglecting any reactance effect. For maximum out-put, then, the impedance of the substation as seen from the line must be equal to the impedance of the line or,

$$R_4 = \frac{ab}{a+b}$$

$$\text{where} \quad a = R_2 \text{ and } b = R_1 \left(\frac{n_1}{n_2} \right)^2 \quad 90$$

$$\text{or} \quad R_4 = \frac{R_2 R_1 \left(\frac{n_1}{n_2} \right)^2}{R_2 + R_1 \left(\frac{n_1}{n_2} \right)^2} \quad 95$$

$$\text{or} \quad R_4 = \frac{R_2 R_1 n_1^2}{R_2 n_2^2 + R_1 n_1^2}$$

substituting equation (5)

$$R_2 = R_4 \left(1 + \frac{n_2 n_3}{n_1 n_4} \right) \quad (6) \quad 100$$

Another requirement is that the transmitter must have maximum out-put, which means that the resistance of the circuit supplied by the transmitter must be equal to the resistance of the transmitter itself, or

$$R_1 = R_3 \left(\frac{n_4}{n_3} \right)^2 + R_4 \left(\frac{n_2}{n_1} \right)^2 \quad 110$$

and substituting (4)

$$R_1 = R_4 \left(\frac{n_2 n_4}{n_1 n_3} + \frac{n_2^2}{n_1^2} \right)$$

$$\text{or} \quad R_1 = R_4 \left(\frac{n_1 n_2 n_4 + n_2^2 n_3}{n_1^2 n_3} \right) \quad (7) \quad 115$$

Collecting equations (4), (6), and (7) we have convenient design formulae expressing the impedance of the various elements in terms of the line impedance and the transformer ratios;

$$\left. \begin{aligned} R_3 &= R_4 \left(\frac{n_2 n_3}{n_1 n_4} \right) \\ R_2 &= R_4 \left(1 + \frac{n_2 n_3}{n_1 n_4} \right) \\ R_1 &= R_4 \left(\frac{n_1 n_2 n_4 + n_2^2 n_3}{n_1^2 n_3} \right) \end{aligned} \right\} \text{A.} \quad 125$$

Fig. 7 is a modification of the substation of 130

my invention adapted for use on common battery systems.

The operation during transmission is shown in Fig. 8 and is as follows; the action of the transmitter supplies alternating current to the line L, and auxiliary resistance X, in series, the instantaneous direction of current flow being indicated by the arrows. Windings N₁ and N₃ are in bridge of the line and auxiliary resistance respectively, and they induce voltages in windings N₂ and N₄ respectively. The substation being properly designed and so connected that the voltages induced in windings N₂ and N₄ will be equal and opposite, and no current will flow in the receiver circuit.

The action while receiving is shown in Fig. 9 and is the same as for Fig. 3 except that the receiver and transmitter are interchanged. The design formulæ for this modification are very similar to those for Fig. 1, and may be derived in a similar manner since the only difference is an interchange of position of transmitter and receiver.

The design formulæ for Fig. 7 are:

$$\left. \begin{aligned} R_1 &= R_4 \left(1 + \frac{n_2 n_3}{n_1 n_4} \right) \\ R_3 &= R_4 \left(\frac{n_2 n_3}{n_1 n_4} \right) \\ R_2 &= R_4 \left(\frac{n_1 n_2 n_4 + n_2^2 n_3}{n_1^2 n_3} \right) \end{aligned} \right\} B.$$

It can readily be seen that modifications of the substation of my invention, other than those which I have here shown, can be had by simply inter-changing the positions of the various elements, and consequently my invention is not to be limited to the particular forms shown. It will be understood, also, that, since ideal conditions have been assumed, I do not desire to limit the design of the substation of my invention to the design formulæ set forth in this specification, but may modify the design to allow for actual conditions found in practice. The design formulæ set forth in this specification have been given to show only the fundamental relations existing in the substation of my invention.

What I claim is:

1. In a two way signaling system, the combination of two transformers each having a plurality of windings, and four component elements consisting, respectively, of a circuit for the transmission and reception of signals, a receiving circuit proper, a balancing circuit proper, and a transmitting circuit, three of said component elements forming a serial circuit, one winding each of said transformers bridging separately two of said component elements in said serial circuit, the remaining fourth component element forming another serial circuit with

windings of said transformers, said serial circuit being inductively related to first named serial circuit, said elements being so proportioned and related that the impedance of the combination comprising said first named circuit, said receiving circuit proper, said balancing circuit and said transformers, as seen from said transmitting circuit proper, is equal to the impedance of said transmitting circuit proper.

2. In a two way signaling system, the combination of two transformers each having a plurality of windings, and four component elements consisting, respectively, of a circuit for the transmission and reception of signals, a receiving circuit proper, a balancing circuit proper, and a transmitting circuit, three of said component elements forming a serial circuit, one winding each of said transformers bridging separately two of said component elements in said serial circuit, the remaining fourth component element forming another serial circuit with windings of said transformers, said serial circuit being inductively related to first named serial circuit, said elements being so proportioned and related that said receiving circuit and said transmitting circuit proper are conjugate.

3. In a two way signaling system, the combination of two transformers each having a plurality of windings, and four component elements consisting, respectively, of a circuit for the transmission and reception of signals, a receiving circuit proper, a balancing circuit proper, and a transmitting circuit, three of said component elements forming a serial circuit, one winding each of said transformers bridging separately two of said component elements in said serial circuit, the remaining fourth component element forming another serial circuit with windings of said transformers, said serial circuit being inductively related to first named serial circuit, said elements being so proportioned and related that said balancing circuit and said first named circuit are conjugate.

4. In a two way signaling system, the combination of two transformers each having a plurality of windings, and four component elements consisting, respectively, of a circuit for the transmission and reception of signals, a receiving circuit proper, a balancing circuit proper, and a transmitting circuit, three of said component elements forming a serial circuit, one winding each of said transformers bridging separately two of said component elements in said serial circuit, the remaining fourth component element forming another serial circuit with windings of said transformers, said serial circuit being inductively related to first named serial circuit, said elements being so proportioned and related that the impedance

of the combination comprising said transmitting circuit proper, said receiving circuit proper, said balancing circuit and said transformers, as seen from first named circuit, is equal to the impedance of first named circuit.

5. In a two way signaling system, the combination of two transformers each having a plurality of windings, and four component elements consisting, respectively, of a circuit for the transmission and reception of signals, a receiving circuit proper, a balancing circuit proper, and a transmitting circuit, three of said component elements forming a serial circuit, one winding each of said transformers bridging separately two of said component elements in said serial circuit, the remaining fourth component element forming another serial circuit with windings of said transformers, said serial circuit being inductively related to first named serial circuit, said elements being so proportioned and related that said transmitting circuit and said receiving circuit are conjugate; said first named circuit and said balancing circuit are conjugate; the impedance of the combination comprising said first named circuit, said receiving circuit proper, said balancing circuit and said transformers, as seen from said transmitting circuit proper, is equal to the impedance of said transmitting circuit; and the impedance of the combination comprising said transmitting circuit proper, said receiving circuit proper, said balancing circuit and said transformers, as seen from said first named circuit, is equal to the impedance of said first named circuit.

6. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of said induction coils bridging separately two of said elements in said serial circuit, the fourth element and the remaining two windings of said induction coils forming a separate serial circuit, said circuit being inductively associated with the first mentioned circuit.

7. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of said induction coils bridging separately two of said elements in said serial circuit, the fourth element and the remaining two windings of said induction coils forming a separate serial circuit, said circuit being inductively associated with the first mentioned circuit, the parts being so proportioned, and the connections such, that the transmitter supplies maximum energy without absorption of energy by the receiver.

8. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of said induction coils bridging separately two of said elements in said serial circuit, the fourth element and the remaining two windings of said induction coils forming a separate serial circuit, said circuit being inductively associated with the first mentioned circuit, the parts being so proportioned, and the connections such, that substantially none of the energy supplied by the transmitter shall be absorbed by the receiver.

9. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of said induction coils bridging separately two of said elements in said serial circuit, the fourth element and the remaining two windings of said induction coils forming a separate serial circuit, said circuit being inductively associated with the first mentioned circuit, the parts being so proportioned, and the connections such, that the transmitter supplies maximum effective energy.

10. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of said induction coils bridging separately two of said elements in said serial circuit, the fourth element and the remaining two windings of said induction coils forming a separate serial circuit, said circuit being inductively associated with the first mentioned circuit, the parts being so proportioned, and the connections such, that maximum energy is absorbed by the receiver from the line when receiving.

11. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of said induction coils bridging separately two of said elements in said serial circuit, the fourth element and the remaining two windings of said induction coils forming a separate serial circuit, said circuit being inductively associated with the first mentioned circuit, the parts being so proportioned, and the connections such, that maximum energy is absorbed by the receiver from the line without absorption of energy by said resistance.

12. A telephone apparatus, comprising a line, a transmitter, a receiver and an auxiliary resistance, three of said elements forming a serial circuit, two induction coils having two windings each, one winding each of

said induction coils bridging separately two
of said elements in said serial circuit, the
fourth element and the remaining two wind-
ings of said induction coils forming a sepa-
5 rate serial circuit, said circuit being induc-
tively associated with the first mentioned
circuit, the parts being so proportioned, and
the connections such, that the transmitter
supplies maximum energy to the line without
10 absorption of energy, by the receiver when
the apparatus is transmitting, and maxi-
mum energy is absorbed by the receiver

from the line when the apparatus is receiv-
ing, without absorption of energy by said
resistance.

15

In testimony whereof, I have signed my
name to this specification in the presence of
two subscribing witnesses, this thirteenth
day of June, 1919.

PAUL J. HACKETT.

Witnesses:

H. J. FARRAR,
C. B. McCoy.