

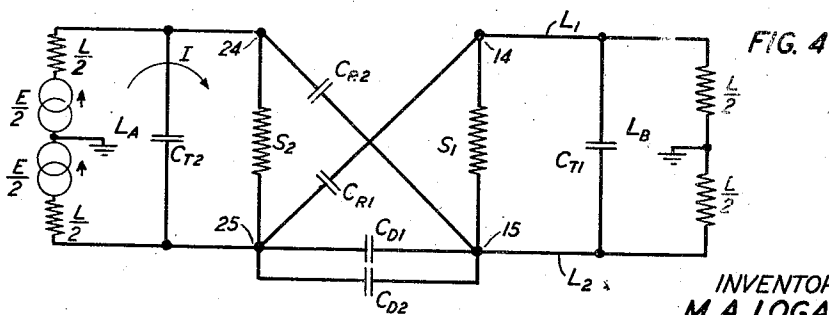
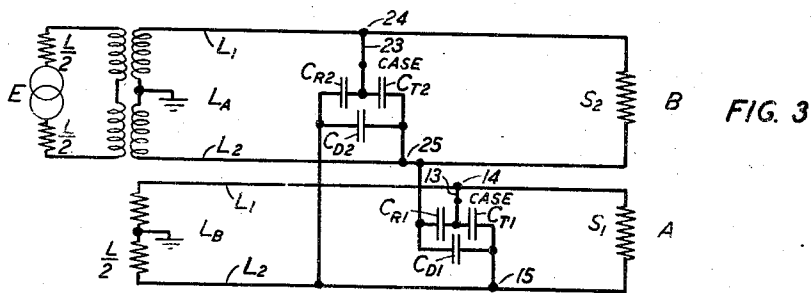
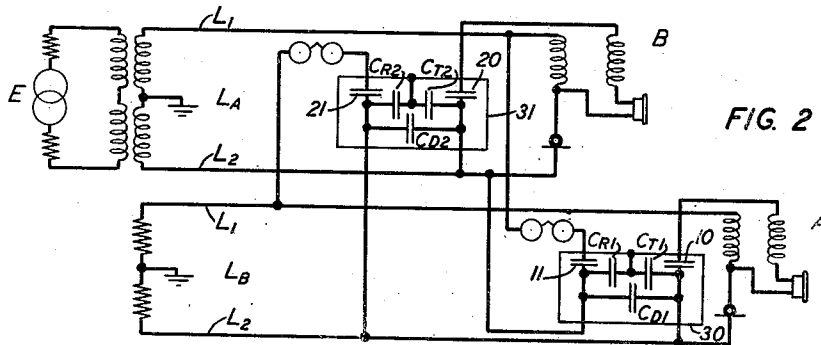
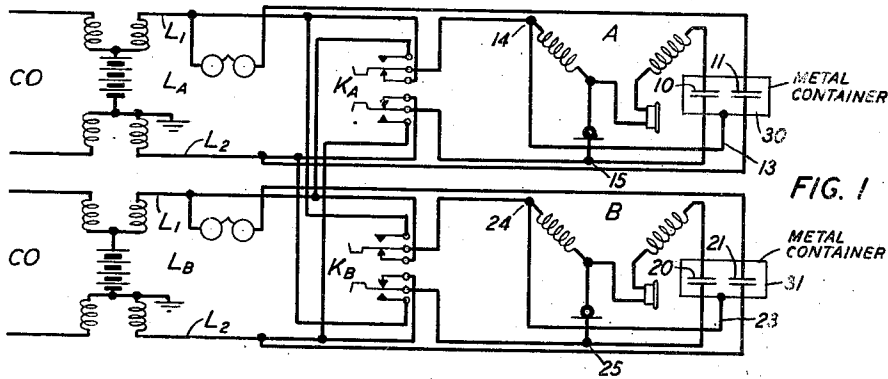
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TELEPHONE SYSTEM

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TELEPHONE SYSTEM

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10 Claims. (Cl. 179—79)

This invention relates to telephone transmission circuits and particularly to means for preventing disturbances, such as cross-talk, in the operation of telephone communication circuits.

5 It is the object of this invention to reduce cross-talk between communication circuits of the type in which the ringing and talking capacitors of the associated substation circuits are housed in the same container and in which conditions
10 necessitate the electrical association of a capacitor of one line with a capacitor of another line.

In what are known as combined hand telephone sets, it is the practice to house all of the subscriber's station equipment, such as the transmission induction coil and associated condenser
15 and the ringer and its associated condenser in the base of the telephone set. For the purpose of further conserving space, it has been found desirable to house the condensers of the talking and ringing circuits in a common container.
20 Such a construction gives rise to natural internal capacities, such as the direct capacity between the two condensers and the capacities between each condenser and the casing in which the condensers are housed, which must be reckoned with
25 in the design of certain telephone facilities, such as those furnished by key telephone sets.

The key telephone set provides facilities which render it possible for a subscriber to utilize his
30 telephone equipment in answering or initiating calls on lines other than the line to which his equipment is normally connected. In order that the subscriber's line from which the station equipment has been transferred while a call on another
35 line is being handled, be made available for use by another subscriber having the same facilities, it has been found practicable to interpose the switching equipment, or keys, between the ringer bridge and the speech transmitting and receiving
40 equipment of each line so that when such keys are operated, the ringer circuit is undisturbed in so far as its connection to the line is concerned and only the speech transmitting and receiving circuits are switched to the other line.
45 It follows, therefore, that under such conditions wherein subscribers are utilizing lines other than the ones to which their talking equipment is normally connected, the ringing capacitor of each line is electrically associated with a talking capacitor of the other line. Thus a condition conducive to cross-talk between lines results due to the capacitive coupling between capacitors housed
50 in the same container but electrically associated with different lines.

55 In accordance with a feature of this invention,

this condition of cross-talk is minimized by conductively connecting the container, which houses the capacitors of the line circuit with a particular conductor of the line with which it is associated and by so designing the capacitor housing that a particular relationship exists between
5 the direct capacity between the talking and ringing capacitors, and the capacity between the ringing capacitor and the case. More specifically, the internal separators of the condensers and their housing are so dimensioned as to make the
10 direct capacity between the two condensers equal to the capacity between the ringing condenser and the casing, and an electrical connection is extended from the casing to the line conductor
15 opposite to the one in which the talking condenser is included.

The invention will be readily understood from the following detailed description made with reference to the accompanying drawing in which:
20

Fig. 1 is a simplified key equipment telephone circuit involving the features of the invention;

Fig. 2 is a circuit schematic illustrating the capacity coupling condition which prevails when the keys of Fig. 1 are actuated to connect the subsets to alternate lines, and without the casing connection to the line conductor. This figure also shows the various capacities which must be reckoned with in solving the problem of cross-talk;
30

Fig. 3 is a modification of Fig. 2 showing the distribution of the objectionable capacities when the containers are connected to a line conductor; and

Fig. 4 is a circuit schematic evolved from Fig. 3 and illustrates more clearly the manner in which the objectionable capacities are distributed by connecting the capacitor container to one of the line conductors.

The simplified key equipment telephone system
40 illustrated in the drawing comprises but two stations A and B. Each station includes the usual induction coil, transmitter, receiver, transmission condenser and the signaling equipment comprising a ringer and ringing condenser. The numerals 10 and 11 identify the transmission
45 condenser and ringing condenser, respectively, at station A while the numerals 20 and 21 identify the corresponding elements at station B. The condensers 10 and 11 at station A are housed in a single container 30 whereas the single container
50 31 houses the condensers 20 and 21 of station B.

The substation equipment at station A, excluding the ringing condenser 11 and its associated ringer, is normally connected to the line
55

conductors of line L_A by way of the normal contacts of key K_A . The substation equipment at station B, excluding the ringing condenser 21 and its associated ringer, is normally connected to the line conductors of line L_B by way of the normal contacts of key K_B . The alternate contacts of key K_A are electrically connected to the line conductors of line L_B whereas the alternate contacts of key K_B are electrically connected to the line conductors of line L_A . The ringing circuit of each line is permanently connected across the conductors of its respective line on the central office side of the respective switching keys K_A and K_B .

15 A call originating at the central office, or at some other outside point, on either of the lines L_A or L_B will result in the actuation of the ringer associated with the line on which the call is incoming, in accordance with well-known practice and the party whose substation equipment is normally associated with the line whose ringer is actuated will respond to the signal in the well-known manner.

In the event that the party for whose station the call is intended is not available, the other party may pick up the call. For descriptive purposes, it will be assumed that a call incoming on line L_A and intended for the party at station A who is not available to answer the call, is picked up by the party at station B. To effect such a pick-up, the party at station B actuates the key K_B which transfers the speech receiving and transmitting equipment from the line L_B to the line L_A , and proceeds to answer the call in the usual manner. It will be noted that the actuation of key K_B does not remove the station ringer and its associated condenser 21 from line L_B .

Should the party at station A return and desire to use his telephone while the party at station B is utilizing the line L_A , or should the ringer associated with line L_B be actuated to indicate a call incoming on line L_B while the party at station B is conversing on line L_A , the party at station A may actuate the key K_A to transfer his speech receiving and transmitting equipment to the line L_B and thus utilize the line L_B for communication purposes. The actuation of key K_A does not remove the ringer and its associated condenser 11 from the line L_A .

Under the assumed conditions, the party at station A is conversing on the line L_B while the party at station B is conversing on line L_A . It will also be noted that condenser 10, which is housed with condenser 11 in container 30 is associated with line L_B , whereas the condenser 11 is still connected to the line L_A . In like manner, the condenser 20 is associated with line L_A while the condenser 21, which with condenser 20 is housed in the container 31 is connected to the line L_B . Unless provision was otherwise made, the direct capacities between condensers 10 and 11, which condensers are now associated with different lines, and the capacities between each condenser and the container 30, as well as the direct capacity between condensers 20 and 21, which condensers are now connected to different lines and the capacities between each of these condensers and the container 31 would produce an electrostatic coupling of the lines L_A and L_B . With the lines L_A and L_B electrostatically coupled in this manner a condition of cross-talk would prevail which would manifest itself as disturbance to the conversing parties. In effect, the conversation being carried on over line L_A would be overheard by the parties conversing on line L_B

and the conversation carried on over line L_B would be audible to the parties conversing on line L_A .

To eliminate this condition of cross-talk, each condenser housing is conductively connected to one of the line conductors of its respective line. These connections are indicated on the drawing by the numerals 13 and 23. The connection to the condenser housing may be made by soldering or in any other suitable manner.

The following discussion is made with reference to Figs. 2, 3 and 4 and particularly to Fig. 4 and constitutes an exemplification of the manner in which cross-talk is overcome by connecting the containers 30 and 31 (Fig. 1) to the points 14 and 24 respectively of each conductor of the lines L_A and L_B and by making the direct capacities, C_{D1} and C_{D2} , between the talking and ringing condensers 10 and 11 and 20 and 21 respectively, equal to the capacity C_{R1} and C_{R2} between the ringing condensers 11 and 21 and their respective containers 30 and 31.

In this discussion:

C_{R1} =the capacity between ringing condenser 11 and the container 30

C_{R2} =the capacity between ringing condenser 21 and the container 31

C_{T1} =the capacity between talking condenser 10 and the container 30

C_{T2} =the capacity between talking condenser 20 and the container 31

C_{D1} =the direct capacity between ringing condenser 10 and talking condenser 11

C_{D2} =the direct capacity between ringing condenser 20 and talking condenser 21

L =the line impedance of the lines L_A and L_B

S_1 =the subset impedance of the subset at station A

S_2 =the subset impedance of the subset at station B

E =talking voltage

I_1 =current in subset impedance S_1

In the design of communication circuits of this type it is essential for maximum efficiency in the operation of the substation circuits that the subset impedance, S_1 approximately equal the line impedance L and also the subset impedance S_2 approximately equal the line impedance L , it being understood that the line impedance of the two lines L_A and L_B are approximately the same.

With particular reference to Figs. 3 and 4 it will be noted that by connecting the container 30 to the point 14 of conductor L_1 of line L_A the total capacity C_{T1} from the talking condenser 10 to the case 30 is connected directly across the tip and ring conductors of the line L_A so that it no longer effects cross-talk. The same condition prevails with respect to C_{T2} and the line L_B . The capacities C_{R1} and C_{R2} , from the ringing condensers to the containers 30 and 31 are connected across conductor L_1 of line L_A and conductor L_2 of line L_B and across conductor L_1 of line L_B and conductor L_2 of line L_A , respectively, and the direct capacities C_{D1} and C_{D2} are connected across conductor L_2 of line L_A and conductor L_2 of line L_B . With this circuit arrangement these are the only capacities which serve to produce cross-talk and are the electrostatic couplings between the lines L_A and L_B .

In the following discussion it will be assumed that the subscriber at station B is conversing with another subscriber over the line L_A and that subscriber at station A initiates a call over line L_B . The station A, under these conditions becomes

the disturbed station and it need only be proved that the cross-talk current in the subset impedance S_1 , which represents the disturbed station A, is zero, in order to show that cross-talk is eliminated.

The source of speech currents in Fig. 4 is indicated as two independent sources

$$\frac{E}{2}$$

with their junction connected to ground. This showing is accurate since, in considering cross-talk, we are concerned only with the alternating current component of the central office battery and this battery, as shown in Fig. 1, is connected between both line conductors of line L_A with one terminal grounded, so that one-half the line impedance L appears on either side of the talking battery.

In proving the cross-talk current in S_1 , the disturbed set, is zero, each voltage to ground and the resultant current which flows through the disturbed set S_1 will be considered independently of other voltages and currents and finally, the algebraic sum of all the currents through S_1 will be computed. This method of demonstration of the invention depends upon the "Superposition Theorem" set forth on page 50 of the 1929 edition of "Transmission Networks and Wave Filters" by T. E. Shea, published by D. Van Nostrand Co. Inc.

The speech voltage E causes a current I to flow in the wiring plan as indicated by the curved arrow in Fig. 4. The value of this current may be represented by the following equation:

$$I = \frac{E}{L + S_2} \quad (1)$$

but $L = S_2$ as above indicated, therefore

$$I = \frac{E}{2L} \quad (2)$$

Next, the voltage to ground at point 24 will be determined. This voltage may be represented by the following equation:

$$e_{24} = \frac{E}{2} = I \times \frac{L}{2} \quad (3)$$

Substituting

$$\frac{E}{2L}$$

for I ,

$$e_{24} = \frac{E}{2} - \frac{E}{2L} \times \frac{L}{2} \quad (4)$$

and solving,

$$e_{24} = \frac{E}{4} \quad (5)$$

Similarly the voltage to ground at point 25 is

$$e_{25} = -\frac{E}{4} \quad (6)$$

The equivalent voltage to ground from point 24 causes a small current to flow through C_{R2} to the point 15 and from this point to ground by two paths, one including the subset impedance S_1 and the impedance

$$\frac{L}{2}$$

of the line L_B and the other including only the impedance

$$\frac{L}{2}$$

of the line L_B . Since L and S are approximately equal (a requirement for maximum efficiency in the operation of the subset at station A) only one-quarter of the current through C_{R2} will traverse S_1 , flowing from 15 to 14. The current through C_{R2} may thus be represented closely by the following equation when the impedance of C_{R2} is very high compared to L or S_1 :

$$I_{CR2} = \frac{E}{4} + \frac{1}{j\omega C_{R2}} \text{ or } \frac{Ej\omega C_{R2}}{4} \quad (7)$$

The part of this current which flows upwards through S_1 is, as above indicated, one-quarter of

$$\frac{Ej\omega C_{R2}}{4}, \text{ or } \frac{Ej\omega C_{R2}}{16} \quad (8)$$

In a similar manner, it is determined that the current through C_{R1} caused by the voltage

$$-\frac{E}{4} \quad (9)$$

appearing between the point 25 and ground is

$$I_{CR1} = -\frac{E}{4} + \frac{1}{j\omega C_{R1}} \text{ or } -\frac{Ej\omega C_{R1}}{4} \quad (9)$$

As in the previous case, the part of this current which flows through S_1 is one-quarter of

$$-\frac{Ej\omega C_{R1}}{4} \quad (10)$$

or

$$-\frac{Ej\omega C_{R1}}{16} \quad (10)$$

which current flows from 14 to 15, that is, in the opposite direction to I_{CR2} .

The current through S_1 due to C_{R2} and C_{R1} is, therefore,

$$I_{S1} = \frac{Ej\omega C_{R2}}{16} - \left(-\frac{Ej\omega C_{R1}}{16} \right) \quad (11)$$

or

$$\frac{Ej\omega C_R}{8}, \text{ since } C_{R1} = C_{R2} \quad (12)$$

The current through C_{D1} due to the voltage

$$-\frac{E}{4} \quad (13)$$

from the point 25 to ground is

$$-\frac{E}{4} + \frac{1}{j\omega C_{D1}} \text{ or } -\frac{Ej\omega C_{D1}}{4} \quad (13)$$

In like manner the current through C_{D2} due to the voltage

$$-\frac{E}{4} \quad (14)$$

from the point 25 to ground is

$$-\frac{E}{4} + \frac{1}{j\omega C_{D2}} \text{ or } -\frac{Ej\omega C_{D2}}{4} \quad (14)$$

The total current to the point 15 through C_{D1} and C_{D2} is therefore,

$$-\frac{Ej\omega C_{D1}}{4} + \left(-\frac{Ej\omega C_{D2}}{4} \right) \quad (15)$$

or

$$-\frac{Ej\omega C_D}{2}, \text{ since } C_{D1} = C_{D2} \quad (16)$$

This current divides at point 25 and one-quarter of it flows through S_1 in the same direction as I_{CR2} . This value of current is then

$$-\frac{Ej\omega C_D}{8} \quad (17)$$

By algebraically adding Equations (12) and (17) the total current through S_1 is

$$\frac{E_j \omega C_R}{8} - \frac{E_j \omega C_D}{8} \text{ or } \frac{E_j \omega}{8} (C_R - C_D) \quad (18)$$

Since C_R is equal to C_D the value of the current through S_1 is zero, thus showing an absence of cross-talk current in the substation circuit S_1 which corresponds to the substation circuit at station A.

It is clear from the above discussion and computation that the electrostatic coupling between the two lines is caused by C_{R2} , C_{R1} , C_{D2} and C_{D1} and the value of the cross-talk current in S_1 due to this coupling is zero. Hence, cross-talk between the two lines is eliminated by making the direct capacities between the ringing and talking capacitors equal to the capacities between the ringing capacitors and their respective containers. It is also understood that the two units, each involving a ringing capacitor and a talking capacitor are identical so that C_{R1} equals C_{R2} and C_{D1} equals C_{D2} .

Though the above discussion has been confined to proving an absence of cross-talk current in S_1 , by an identical procedure the value of cross-talk current in S_2 due to speech currents in line L_B may also be shown to be zero.

What is claimed is:

1. A subscriber's telephone set comprising in combination a speech transmitting and receiving circuit and a signal circuit, a metal container, a condenser included in said speech transmitting and receiving circuit and housed in said container, a condenser included in said signal circuit and housed in said container, said condensers being so separated one from the other and from the container that the capacity between said second condenser and said container equals the direct capacity between the condensers, and a connection from said container to a terminal of said speech transmitting and receiving circuit whereby the internal capacity between said first condenser and said container is effectively connected across the terminals of said speech transmitting and receiving circuit.

2. In a telephone system, a pair of telephone lines each having a speech transmitting and receiving circuit including a condenser normally connected to the line, a signaling circuit including a condenser permanently connected to the line and a metal container housing the condensers, means for transferring the speech transmitting and receiving circuit of each line to the other line whereby the condensers housed in the same container are electrically included in different lines and the said lines are thus electrostatically coupled, and means for eliminating cross-talk resulting from such coupling comprising a conductive connection between each of the containers and a line conductor of its associated line circuit.

3. In a telephone system, a first telephone line having a telephone set comprising talking and ringing equipments each containing a capacitor, a second telephone line having a telephone set comprising talking and ringing equipments each containing a capacitor, a metallic container for each group of capacitors of each line, switching means for connecting the talking equipment of said first line with the ringing equipment of said second line and the talking equipment of said second line with the ringing equipment of said first line whereby the capacitors housed in the same containers are effectively

included in different lines, and means for reducing cross-talk between the two lines due to the capacitive coupling between the capacitors included in different lines but housed in the same container, said means comprising a conductive connection from each container to a conductor of its respective line.

4. In a telephone system, a line circuit comprising two sections interconnected by a switching device, a ringer circuit including a capacitor connected across one of said sections and the other section terminating in speech receiving and transmitting equipment including a capacitor, said two capacitors being housed in the same metallic container, a second line comprising two sections interconnected by a switching device, a ringer circuit including a capacitor connected across one section of said second line and the other section thereof terminating in speech receiving and transmitting equipment including a capacitor, the capacitors of said second line being housed in the same container, means including cross-connections between said lines for connecting the speech receiving and transmitting section of said first line with the ringer section of said second line and the speech receiving and transmitting section of said second line with the ringer section of said first line upon the actuation of said switching devices, whereby the capacitors housed in the same containers are connected in different line circuits and the different line circuits are electrostatically coupled and means for reducing cross-talk between the two lines due to the electrostatic coupling, said means comprising a conductive connection from each of the capacitor containers to a similar conductor of their respective line circuits.

5. In a telephone system, a pair of lines each having a pair of capacitors connected thereto and housed in a single metallic container, a connection involving said lines in which one of the capacitors in each of said pairs is electrically disconnected from its own line and connected to the other line whereby said lines are electrostatically coupled by the capacities existing between each of the capacitors and their respective containers and the direct capacity between the capacitors housed in the same container, and means for reducing cross-talk produced by the electrostatic coupling, said means comprising a connection from each of said containers to one of the line wires of its respective line.

6. In a telephone system, a pair of telephone lines each having a ringer circuit and a speech receiving and transmitting circuit and each of said circuits including a capacitor, a metallic container housing the capacitors of each line, means for interconnecting said lines so that the ringer circuit of each of said lines is associated with the speech receiving and transmitting circuit of the other line whereby said lines are electrostatically coupled by the capacities existing between each of the capacitors and their respective containers and the direct capacities between the capacitors housed in the same containers, and means for reducing cross-talk produced by said coupling, said means comprising a connection from each container to one of the conductors of the line with which the containers are associated.

7. In a telephone system, a telephone line having a speech transmitting and receiving circuit including a condenser and a signal circuit including a condenser, a metal container housing said condensers, said first condenser effecting a ca-

capacity C_r with said container, said second condenser effecting a capacity C_r with said container and said two condensers effecting a direct capacity C_d therebetween, a second telephone line, 5
 switching means in said first line for transferring the speech transmitting and receiving circuit thereof to said second line whereby the condensers housed in said container are electrically included in different lines, and a connection from 10
 said container to a line conductor of said first line whereby the direct capacity C_d is connected between similar conductors of the two lines, the capacity C_r is connected between dissimilar conductors of the two lines and the capacity C_r is connected across the two conductors 15
 of said first line when said switching means is operated.

8. In a telephone system, a telephone line having a speech transmitting and receiving circuit including an induction coil and a condenser, and 20
 a signal circuit including a condenser, a metal container housing said condensers, said first condenser effecting a capacity C_r with said container, said second condenser effecting a capacity 25
 C_r with said container and said two condensers effecting a direct capacity C_d therebetween and said condensers and said container being so relatively disposed that the direct capacity C_d equals the capacity C_r , a second telephone line, switching 30
 means in said first line for transferring the speech transmitting and receiving circuit thereof to said second line whereby the condensers housed in said container are electrically included in different lines and a connection from said container to a point on a conductor of said first line 35
 intermediate said switching means and the induction coil of said first line whereby the direct capacity C_d is connected between similar conductors of the two lines, the capacity C_r is connected between dissimilar conductors of said 40
 lines and the capacity C_r is connected across the two conductors of said first line when said switching means is operated.

9. In a telephone system, a pair of telephone

lines, each line having a speech transmitting and receiving circuit including an induction coil and a condenser and a signal circuit including a condenser, a separate metal container housing both 5
 the condensers of each of said lines, said first condenser of each line effecting a capacity C_r with its respective container said second condenser of each line effecting a capacity C_r with its respective container and said two condensers 10
 of each line effecting a direct capacity C_d equal to the capacity C_r , switching means for each of said lines for transferring the speech transmitting and receiving circuit thereof to the other line whereby said first condenser of said first line 15
 and said second condenser of said second line are electrically included in said second line and said second condenser of said first line and said first condenser of said second line are electrically included in said first line, and a connection from 20
 each of the containers to the line terminal of the induction coil of the speech transmitting and receiving circuit of its associated line whereby, when said switching means are operated, the direct capacities C_d are connected between similar 25
 conductors of the two lines, the capacities C_r are connected between dissimilar conductors of the two lines and the capacities C_r are each connected across the two line conductors of separate lines.

10. A subscriber's telephone set comprising a 30
 speech transmitting and receiving circuit, a signal circuit, a condenser unit comprising a pair of condensers housed in a metal container and so disposed relative to each other and to the container that the capacity between one of said condensers and the container equals the direct capacity between the condensers, the said one of 35
 said condensers being included in said signal circuit and the other condenser being included in said speech transmitting and receiving circuit 40
 and a conductive connection between the container and a terminal of said speech transmitting and receiving circuit.

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