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TRANSMISSION CIRCUIT

Filed Aug. 14, 1930

FIG. 1

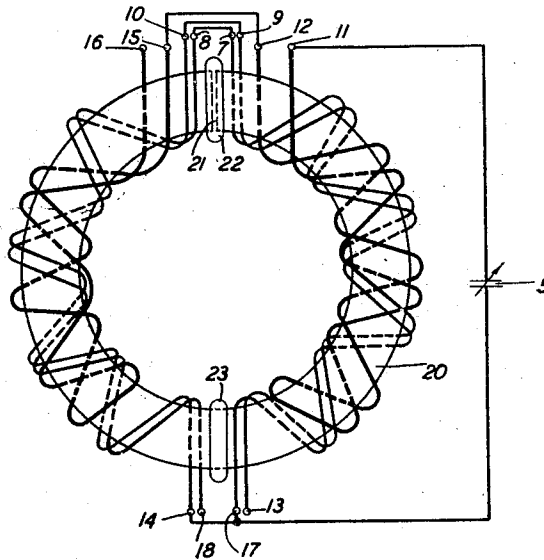


FIG. 2

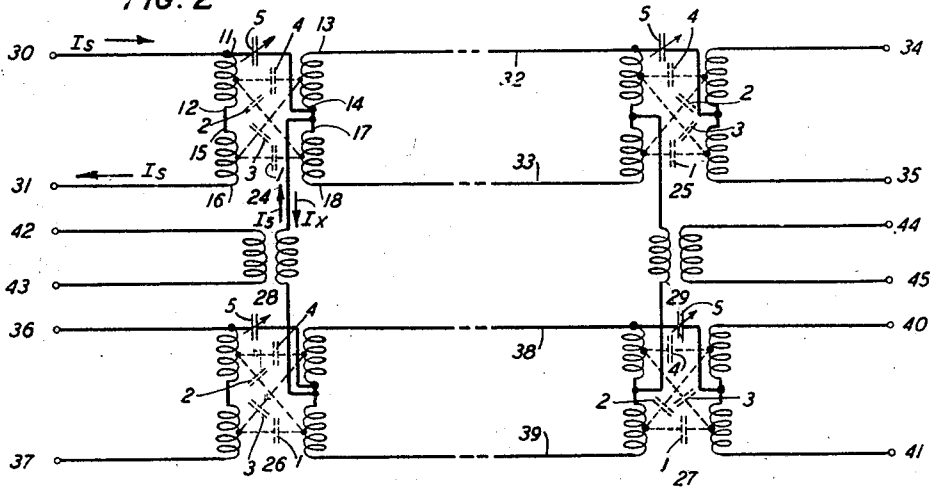
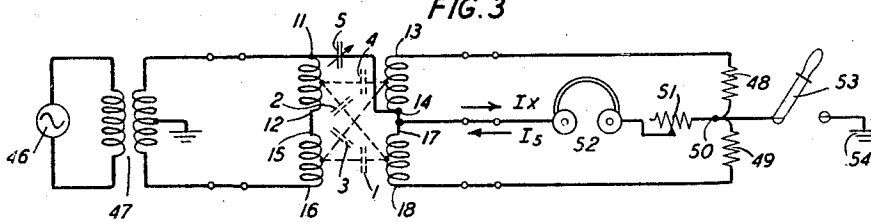


FIG. 3



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TRANSMISSION CIRCUIT

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This invention relates to transmission circuits and pertains more especially to the reduction of crosstalk in speech transmission circuits in which repeating coils are employed for providing phantom circuits.

It is an object of this invention to provide means and methods for eliminating the crosstalk in phantom circuits in which repeating coils are employed.

The repeating coils or transformers employed for this purpose should have their windings as symmetrical with respect to the tapping point as is possible in order to reduce crosstalk to a minimum.

Among the factors contributing to crosstalk between the phantom and side circuits are inductance unbalance between the two halves of the winding to which the phantom circuit is physically connected, resistance unbalance between the two halves of the winding to which the phantom circuit is physically connected, distributed capacity unbalance between the two halves of the winding to which the phantom circuit is physically connected, mutual impedance unbalance between the windings of the repeating coil and admittance unbalance between the windings of the repeating coil.

The first four causes of crosstalk referred to above can be eliminated by methods well known in the prior art, such as twisted pair windings and balancing resistances and capacitances.

The fifth cause of crosstalk referred to above is due to the capacity which exists between the primary or drop winding and the winding which forms a part of the phantom circuit or line winding. In a coil of this type there is a capacity between one-half of the line winding and one-half of the primary or drop winding, a second capacity between the same half of the line winding and the other half of the primary or drop winding, a third capacity between the other half of the line winding and the first mentioned half of the primary or drop winding, and a fourth capacity between the last mentioned half of the line winding and the second mentioned half of the primary or drop winding. Since the two halves of the line winding are formed

by a twisted pair, the first and third capacities mentioned will be practically equal and the second and fourth capacities mentioned will be practically equal. However, since the two halves of the primary or drop winding are wound on opposite halves of the core, the sum of the first and third capacities will not necessarily be equal to the sum of the second and fourth capacities. When the sum of the first and third capacities is different from the sum of the second and fourth capacities, the result is an effective residual capacity, equal to the difference between the two sums, acting from the primary or drop winding to the line winding.

This effective residual capacity will in effect introduce a current in the phantom circuit when a current flows in the side circuit. The effective current flowing in the phantom circuit will be proportional to the magnitude of the residual capacity and the difference of potential between its terminals. All the effective current flowing through residual capacity will not flow into the phantom circuit through the physical connection to the side circuit, but this current will be divided between the three conductors leading from the line winding of the repeating coil. The amount of the effective current flowing to the side circuit and the amount flowing to the phantom circuit will depend upon the relative impedance characteristics of the different paths.

It is an object of this invention to eliminate the crosstalk in phantom circuits due to the admittance unbalance between the windings of the repeating coil.

If a small variable condenser of any suitable type is introduced between two points that have a difference in potential opposite to that of the residual capacity and the capacity of this condenser is adjusted, the crosstalk can be balanced out or eliminated.

A feature of the invention is, therefore, the use of a small capacity to balance out or neutralize the admittance unbalance between the windings of the repeating coil.

To determine the value of the added capacity necessary to balance out or eliminate the crosstalk due to capacity unbalance of

the windings of each individual repeating coil, the repeating coil is preferably connected in a bridge or measuring circuit having balanced ratio arms and with the ratio arms ungrounded the coil is adjusted for self and mutual impedance and resistance unbalance. When the current has been reduced to a minimum in a receiver connected from the tapping point, or point of physical connection of the phantom circuit to the point of connection of balanced ratio arms, it indicates that these unbalances are eliminated. With the coil connected in the bridge circuit in this manner no admittance currents can flow due to the effective residual capacity between the windings as there is no return path for these currents. The mid-point of the balanced ratio arm is then grounded which provides a return path to the grounded source causing current to flow through the effective residual capacity between the windings. The small variable condenser is then introduced between two points in the coil which have a difference of potential opposite to that of the capacity unbalance and this condenser is adjusted until the crosstalk is balanced out or eliminated.

As this condenser can in most cases be very small, it is preferably formed by twisting two insulated conductors together, or by winding bare wire around an insulated conductor and soldering the turns of the bare wire together to form a sheath, although any suitable variable capacitance will be satisfactory for this purpose. The capacity can be varied changing the length of wire twisted together or the length of the sheath formed by the bare wire. The advantage in employing this type of condenser is that it can be firmly secured to the coil after adjustment.

The invention will be better understood by reference to the accompanying drawings and detailed description thereof, in which:

Fig. 1 is a schematic drawing of a phantom repeating coil;

Fig. 2 is a schematic drawing of a phantom circuit employing repeating coils of the type shown in Fig. 1; and

Fig. 3 is a schematic drawing of a testing and adjusting circuit for determining when the effective residual capacity between the primary or drop winding and the line winding of the repeating coil is balanced out.

Referring to Fig. 1, a toroidal core 20 of magnetic material, having an airgap 21 and separators 22 and 23 for providing two equal winding sections has been shown as one form of core structure which may be used for repeating coils embodying the present invention, although the invention is also applicable to repeating coils wound on other types of core structures, as for example a toroidal core without an airgap and the so-called "shell type" core with or without an airgap. The line winding 13, 14, 17, 18, is preferably wound adjacent the core and the primary or

drop winding 11, 12, 15, 16 over the line winding. The line winding 13, 14, 17, 18 comprises two windings 13, 14 and 17, 18 connected in series aiding. The winding 13, 14 comprises windings 13, 7 and 8, 14 connected in series aiding, and the winding 17, 18 comprises two windings 17, 9 and 10, 18 connected in series aiding. Windings 13, 7 and 17, 9 comprise a twisted pair of conductors wound on one-half of the core 20 and windings 8, 14 and 17, 9 comprise a twisted pair of conductors wound on the other half of the core 20. The primary or drop winding 11, 16 comprises two windings 11, 12 and 15, 16 connected in series aiding. The winding 11, 12 is wound over the windings 13, 7 and 17, 9. The winding 15, 16 is wound over the windings 14, 8 and 18, 10. A variable condenser 5 is connected from terminal 17, 14 to the terminal 11, to accomplish capacity balance in accordance with the invention.

Referring to Fig. 2, a phantom repeating coil 24, similar in construction to that shown in Fig. 1 and described above has its primary or drop winding 11, 12, 15, 16, connected to a side circuit 30, 31 and its line winding 13, 14, 17, 18 connected to line wires 32 and 33. A phantom repeating coil 25, similar to the repeating coil shown in Fig. 1, connects the other end of line wires 32 and 33 to a side circuit at 34, 35. A phantom repeating coil 26, similar to the repeating coil shown in Fig. 1, has its primary or drop winding connected to a side circuit at 36, 37 and its line winding connected to line wires 38 and 39. A phantom repeating coil 27, similar to the repeating coil shown in Fig. 1, connects the other end of the line wires 38 and 39 to another side circuit at 40, 41.

The primary winding of a repeating coil 28 is connected to a phantom circuit at 42, 43. The secondary winding of the repeating coil 28 is connected between the mid-point of the line winding 13, 14, 17, 18 of the phantom repeating coil 24 at 14, 17 and the mid-point of the line winding of the phantom repeating coil 26. The repeating coil 29 connects the mid-point of the line windings of the phantom repeating coils 25 and 27 to a phantom circuit at 44, 45.

Referring to the phantom repeating coil 24, of Fig. 2, constructed as shown in Fig. 1, it will be seen that there are effective capacities 1, 2, 3 and 4 between the respective winding sections as shown.

Since the two halves 13, 7, 8, 14 and 17, 9, 10, 18 of the line winding 13, 14, 17, 18 are formed by a twisted pair of conductors, the capacity 1 and the capacity 3 will be equal to each other and the capacity 2 and the capacity 4 will be equal to each other. However, since the two halves 11, 12, and 15, 16 of the primary or drop winding 11, 12, 15, 16 are wound on opposite sides of the core 20 the sum of the capacities 1 and 3 will not neces-

sarily equal the sum of the capacities 2 and 4. When the sum of the capacities 1 and 3 differs from the sum of the capacities 2 and 4 the result is an effective residual capacity, equal to the difference of the two sums acting from the primary or drop winding 11, 12, 15, 16 to the line winding 13, 14, 17, 18.

There will then be either more or less current flowing from the side circuit through capacities 3 and 4 to the line winding than through capacities 1 and 2. All of the current flowing from the side circuit through the capacities 1 to 4 inclusive will not tend to flow in the phantom circuit through the physical connection of the repeating coil 28 to the line winding 13, 14, 17, 18, but will tend to divide between three conductors, the one conductor to the line winding 13, 14, 17, 18 at 14, 17 and the other two conductors 32 and 33 leading from the line winding. The amount of current tending to flow to the phantom circuit repeating coil 28 will depend upon the relative impedance characteristics of the three conductor paths. If capacities 1 and 2 tend to cause a current I_{1-2} to flow in the phantom circuit and the capacities 3 and 4 tend to cause a current I_{3-4} to flow in the phantom circuit, the residual current I_x flowing in the phantom circuit will be equal to $I_{1-2} - I_{3-4}$. The variable capacity element 5 is provided by the present invention and is connected from terminals 14, 17 to terminal 11 to produce a current I_s equal and opposite to the current I_x .

Referring to Fig. 3, a phantom repeating coil constructed as shown in Fig. 1 and described above has its primary winding 11, 12, 15, 16 connected to a source of constant frequency 46 through a repeating coil 47, the mid-point of its secondary winding being connected to ground. Two resistances 48 and 49 having the same impedance characteristic are connected in series at 50 and across the line winding 13, 14, 17, 18. A variable resistance 51 and a receiver 52 are connected in series from the connection 50 of resistances 48 and 49 to the connection 14, 17 of the line winding 13, 14, 17, 18. A switch 53 is connected from the connection 50 of resistances 48, 49 and 51 to ground at 54.

The operation of this circuit to test the coil, for instance, for unbalance and to adjust it so as to neutralize the current flowing in the phantom circuit due to the effective residual capacity is as follows: With the switch 53 open the phantom repeating coil is first adjusted for self and mutual impedances and resistance unbalance in the manner well-known in the art and which is indicated by minimum current flow in the receiver 52. With the phantom repeating coil connected in the circuit as shown and with the switch 53 open, no admittance current can flow from the winding 11, 12, 15, 16 to the winding 13, 14, 17, 18 due to the effective residual capacity

between the windings as there is no return path for these currents. Switch 53 is closed, providing a return path to the grounded source 47, which causes a current I_x to flow from the grounded frequency source through the effective residual capacity between the windings due to the connection 14, 17, on the line winding, the receiver 52, resistance 51, switch 53 to ground 54.

The balancing capacity provided by the present invention is then connected from connection 14, 17 on the line winding to a point on the primary or drop winding 11, 12, 15, 16 and is made to have such value as will produce a current I_s between the connection 14, 17 on the line winding and ground which is equal and opposite to the current I_x . (The condenser 5 is preferably connected from 14, 17 on the line winding to either 11 or 16 on the drop winding.) The capacity of condenser 5 is then varied until no current flows in the receiver 52. This completes the adjustment of the phantom repeating coil for the elimination of admittance unbalance.

If desirable, the above adjustment may be made with the phantom repeating coil installed in its permanent position in the phantom circuit and the frequency source 46 and repeating coil 47 located in the central office, in which case any capacity unbalance to ground from the two sides of the line connecting the central office to the winding 11, 12, 15, 16 will be compensated for as will the residual capacity between the windings of the coil.

It is to be understood that the invention is not limited to the specific embodiment that has been shown and described in detail, but only by the scope of the appended claims.

What is claimed is:

1. The method of eliminating admittance unbalance due to the residual capacity unbalance between one winding of a repeating coil and another winding of said repeating coil symmetrical to a center tap, which comprises adding a capacity element between points in said winding which have a potential opposite to that across said residual capacity, and adjusting said capacity element until the admittance currents are balanced out or eliminated.

2. A transformer comprising a core, a divided inner winding on said core wound in a plurality of layers, a divided outer winding wound in a plurality of layers over said inner winding, said transformer having natural capacities between each half of the outer winding and each of the halves of the inner winding, which capacities are unsymmetrically located with respect to the common terminals of the halves of the inner winding, and means comprising a capacity element connected between said common terminal of the halves of the inner winding, and said outer winding for compensating for

said unsymmetrical location of said capacities from the halves of the outer winding with respect to the common terminal of the halves of the inner winding.

5 3. In combination, side and phantom circuits, a repeating coil in one of said side circuits having a divided primary and a divided secondary winding, said windings so
10 related that there exists natural capacities between each half of the primary winding and each of the halves of the secondary winding, and that the capacities between each
15 half of the primary and the two halves of the secondary are equal, but the sum of the capacities between the one half of the primary and the two halves of the secondary
20 differs from the sum of the capacities between the other half of the primary and the two halves of the secondary so as to produce an admittance unbalance current between
25 said windings, and a capacity element connected between said primary and secondary winding which neutralizes said admittance unbalance current.

4. In combination, a transformer having primary and secondary windings and natural capacities between said windings, said secondary winding having a center tap, a source
30 of current connected to said primary winding, an electrical conductor, one end of which is connected to said center tap, an electrical path from the other end of said electrical
35 conductor to said source of current, and means to prevent admittance currents from being transmitted from said primary winding to said source of current over an electrical
40 path comprising said natural capacities, said electrical conductor, and said first mentioned electrical path, said means comprising a capacity element connected between said windings.

5. In combination, two lines, a phantom circuit, a repeating coil associated with each
45 of said lines and having a primary winding and a center tapped secondary winding to which tap the phantom circuit is physically connected, and means for balancing out the admittance currents in each of said repeating
50 coils due to the effective residual capacity unbalance between the windings thereof, said means comprising an auxiliary capacity element connected between points in said windings which have a potential opposite to
55 that across said residual capacity.

6. The method of eliminating admittance unbalance currents from a repeating coil having two windings, at least one of which
60 windings is symmetrical to a center tap, which comprises adjusting said coil for self and mutual impedance and resistance unbalance, testing the coil for admittance currents due to residual capacity unbalance between
65 the windings, adding a capacity element between points in said windings which have a potential opposite to that across said re-

sidual capacity, and adjusting said capacity element until the admittance currents are balanced out or eliminated.

7. In combination, a transformer having primary and secondary windings, and natural capacities between said windings, said secondary winding having a center tap, a source of current connected to said primary
70 winding, an electrical conductor one end of which is connected to said center tap, an electrical path from the other end of said electrical conductor to said source of current and means to prevent admittance currents from being transmitted from said primary
75 winding to said source of current over an electrical path comprising said natural capacities, said electrical conductor, and said first mentioned electrical path, said means comprising a capacity element connected between
80 points in said windings which have a potential opposite to that of the effective residual capacity due to said natural capacities between said primary and secondary windings.

In witness whereof I hereunto subscribe my name this 13th day of August, 1930.

HORACE WHITTLE.

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