Mar. 27, 1923.

1,450,080

L. A. HAZELTINE

METHOD AND ELECTRIC CIRCUIT ARRANGEMENT FOR NEUTRALIZING CAPACITY COUPLING

Filed Aug. 7, 1919 3 sheets-sheet 1

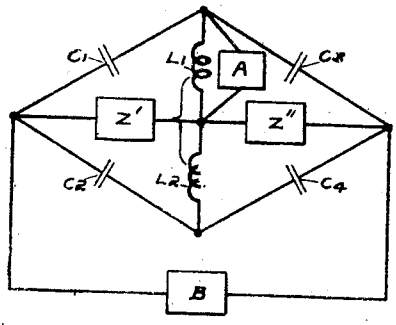


FIG. 1

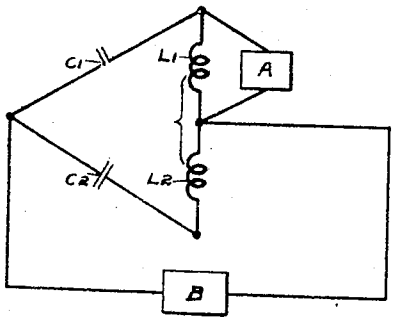
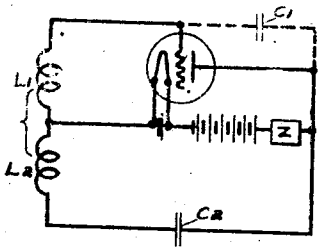


FIG. 2.

FIG. 6



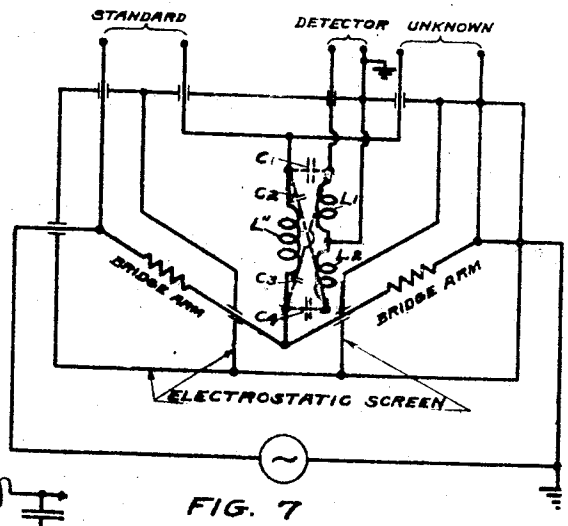


FIG. 7

FIG. 8.

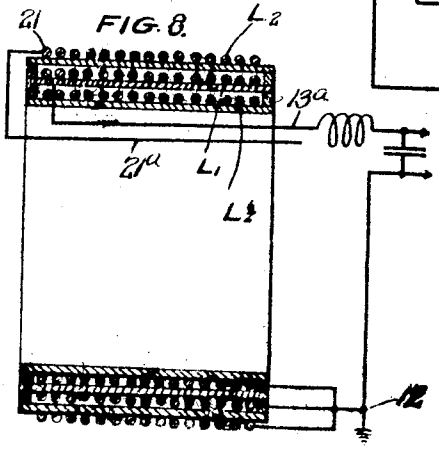


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FIG. 3

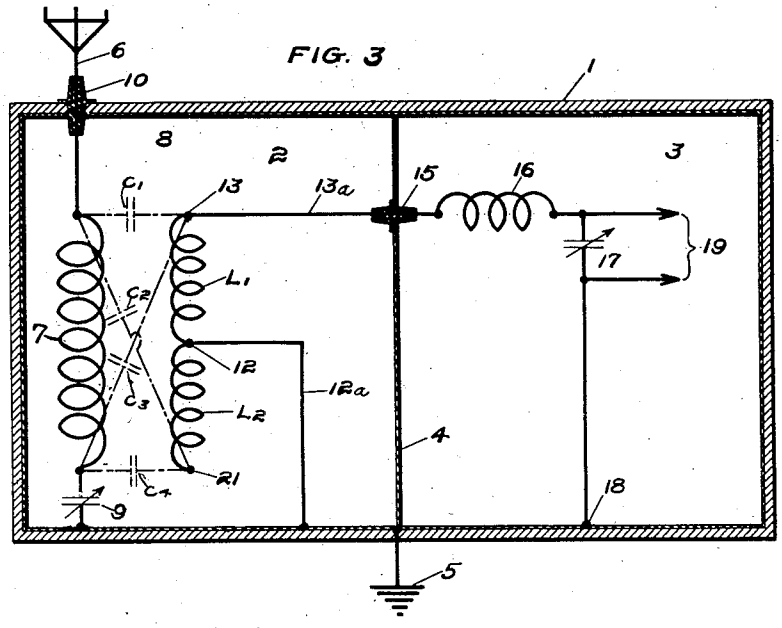

FIG. 4

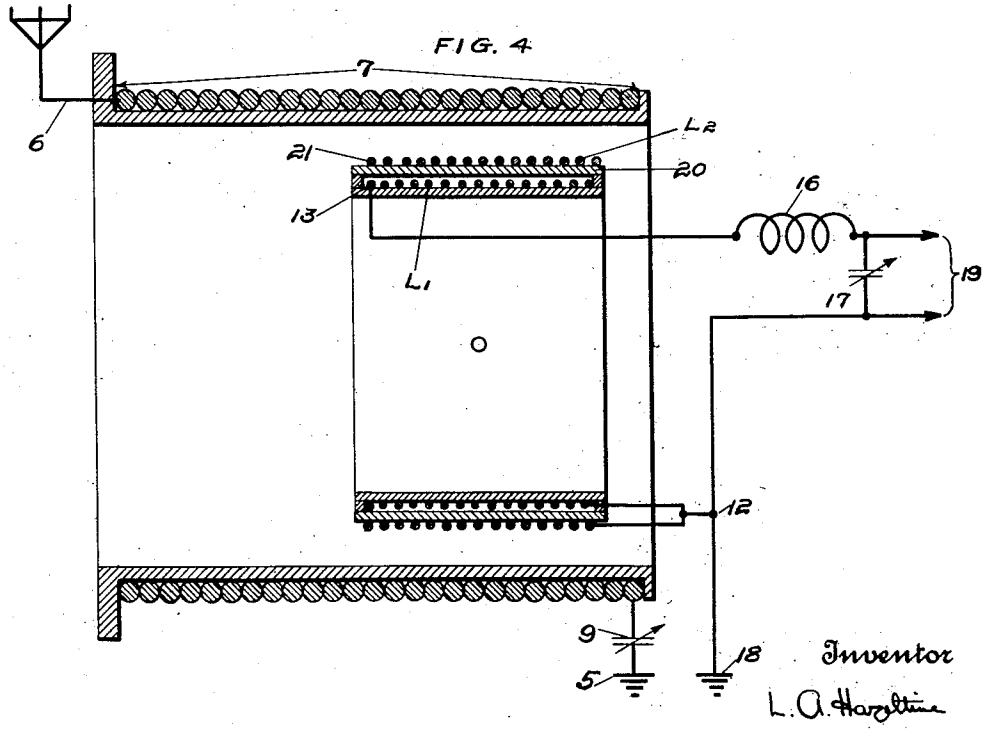

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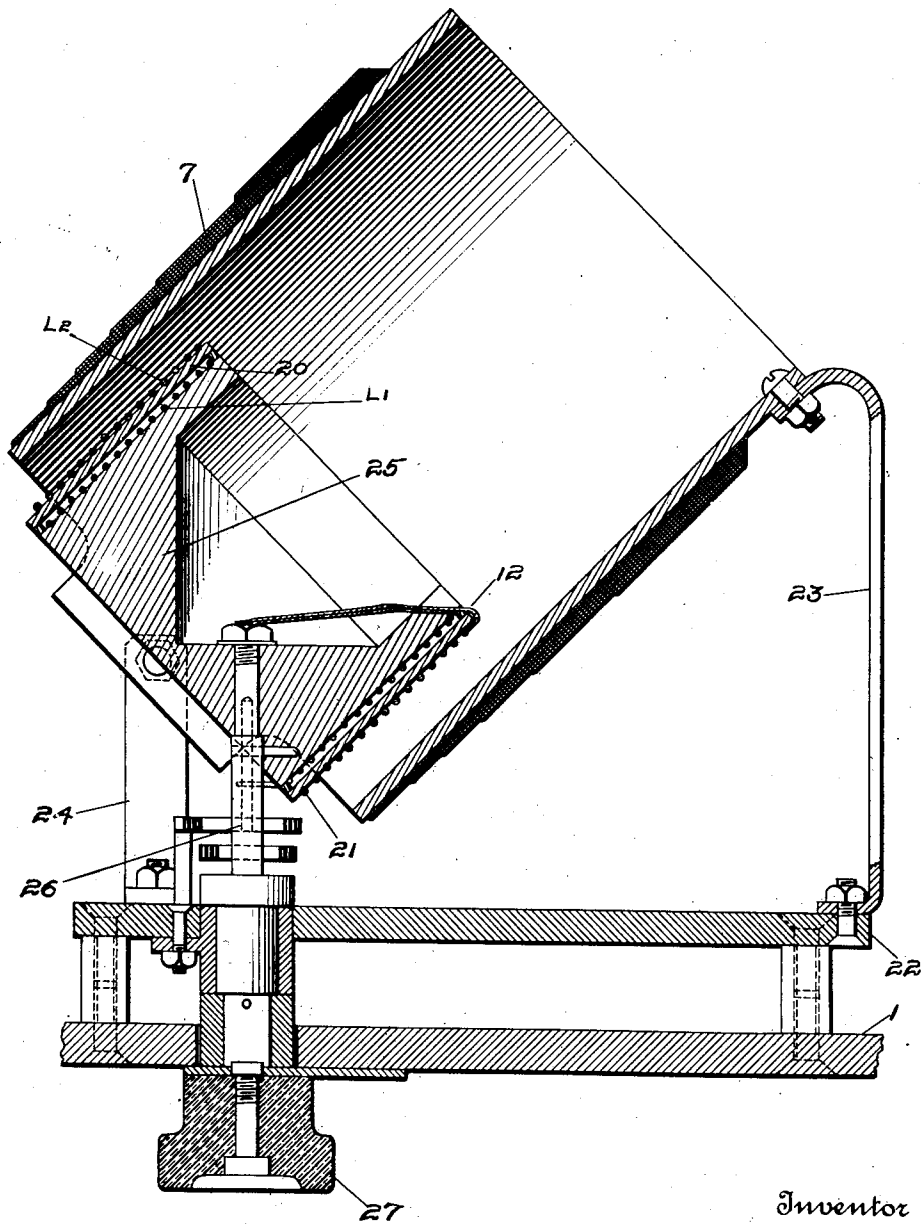
FIG. 5



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UNITED STATES PATENT OFFICE.

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METHOD AND ELECTRIC CIRCUIT ARRANGEMENT FOR NEUTRALIZING CAPACITY COUPLING.

Application filed August 7, 1919. Serial No. 316,007.

To all whom it may concern:

Be it known that I, LOUIS A. HAZELTINE, a citizen of the United States, residing at Hoboken, in the county of Hudson and State of New Jersey, have invented certain Improvements in the Methods and Electric Circuit Arrangement for Neutralizing Capacity Coupling, of which the following is a specification.

This invention relates to the neutralizing of capacity coupling between two electric circuits, which capacity coupling results in the transmitting of undesirable disturbances from one circuit to the other.

It has long been known from practical experience that the presence of capacity coupling between the primary and secondary circuits of a radio receiver results in the transmitting of undesired signal oscillations, particularly those of short wave length, from the primary to the secondary circuit. This reduces the selectivity of the receiver and frequently prevents the reception of the desired signal, which is drowned out by a more powerful signal of a different wave-length. Two methods have been used to reduce the capacity coupling: first, the physical separation of the two circuits by as great a distance as is feasible; and second, the partial enclosing of the circuits in metal screens. Neither method is entirely effective, for the first would require an impracticably wide separation of the circuits; while in the second the metal screens could not completely enclose the circuits as they would then prevent the desired magnetic coupling.

Again, it is well known that capacity coupling between the grid and plate circuits of an audion may result in the production of oscillations. Such oscillations are frequently very undesirable, particularly in audion amplifiers, as they may completely mask the signal which it is desired to amplify.

As a third example of the undesirable effects of capacity coupling, it has been found difficult to arrange a Wheatstone bridge for high-frequency measurements, due to the capacity coupling between the supply circuit and the detector circuit, which may result in a false balance and so vitiate the results of the measurements.

This invention is directed to the elimination of the undesirable effects of capacity coupling between two circuits such as are described in the foregoing examples. This is accomplished briefly as follows: An auxiliary circuit is provided which is electromagnetically coupled to one of the two original circuits which we will call the first circuit, and capacitively coupled to the other, or second circuit. If a disturbing voltage then exists in the second circuit, it will cause currents to flow both in the first circuit and in the auxiliary circuit, due to the capacity couplings. The electro-magnetic coupling between the auxiliary circuit and the first circuit is then arranged so that the magnetic effects of these two currents will neutralize one another and so will result in no voltage across the first circuit. Conversely, if a disturbing voltage exists in the first circuit, it will result in no voltage across the second circuit, by the well known reciprocal properties of electric circuits.

The arrangement of the auxiliary circuit will depend on the forms of the original circuits. In some cases it is necessary to add coils or capacities to the original circuits to provide the required couplings, while in other cases the couplings may be obtained from coils present for other purposes or from inherent capacities.

The principle and certain applications of this invention are illustrated in the accompanying drawings, in which Figure 1 is a circuit diagram showing two capacitively coupled circuit elements which are not directly connected, and the arrangement for neutralizing this capacity coupling. Figure 2 is a corresponding diagram for the case of two circuit elements directly connected; Figure 3 is a wiring diagram showing the arrangement for neutralizing capacity coupling between the primary and secondary circuits of a radio receiver; Figure 4 is a cross-section of the coupling coils and the auxiliary coil in a radio receiver; Figure 5 shows a preferred arrangement of these coils as used in the most advanced type of receiver built for the United States Navy; Figure 6 is a circuit diagram showing the arrangement for neutralizing capacity coupling between the grid and plate circuits of

an audion; Figure 7 is a circuit diagram showing the arrangement for neutralizing capacity coupling to the detector circuit of a Wheatstone bridge; and Fig. 8 is a modified form of secondary winding which may be utilized as an alternative to the arrangement shown in Fig. 4.

Referring to Figure 1, reference characters A and B indicate the circuit elements having undesired capacity coupling thru the capacities C_1 and C_3 and thru the impedances Z' and Z''. Reference character L_1 indicates a coil which may be part of circuit element A or may be additional thereto; L_2 represents the auxiliary coil closely coupled electro-magnetically to L_1 and thence to circuit element A, and at the same time capacitively coupled to circuit element B through capacities C_2 and C_4. The sense of electromagnetic coupling between L_1 and L_2 is such that terminals of unlike polarity are connected together. To understand the principles of this arrangement, first suppose that the two coils are alike and are very closely coupled, that $(C_1=C_2)$ and that $(C_3=C_4)$. Also suppose, just for the moment, that A is removed; then by symmetry a source of voltage in B will cause equal currents to flow through L_1 and L_2 which currents will neutralize one another magnetically; so no voltage will be induced in either coil. Now if A is replaced, it will be connected between two points having no difference in potential and so will not alter the electrical conditions, assuming the resistances of the coils negligible in comparison with their separate reactances. Thus the voltage in circuit element B will not result in a voltage across circuit element A so the effects of capacity coupling will have been neutralized.

More generally in Figure 1, suppose the coils L_1 and L_2 to be unlike, though still closely coupled. If the ratio of turns of L_2 to L_1 is N_2/N_1, then we must have

$$\frac{C_1}{C_2}=\frac{C_3}{C_4}=\frac{N_2}{N_1},$$

in which case the currents of C_1, C_3, and L_1 will be N_2/N_1 times the currents of C_2, C_4, and L_2, respectively, and the magneto-motive force of L_2 will still neutralize that of L_1, giving no induced voltage in either coil.

It should be noted that the above conditions for neutralization impose no limitations on the internal conditions in circuit elements A and B nor on the values of Z' and Z''.

If the impedance Z'' of Figure 1 is replaced by a direct connection, the capacities C_3 and C_4 are directly in parallel with A and L_2, respectively, and so no longer act as coupling capacities. This circuit in effect becomes that of Figure 2, where the same reference characters refer to like parts, C_1 and C_2 remaining the coupling capacities. The condition for neutralization, as before, is simply

$$\left(\frac{C_1}{C_2}=\frac{N_2}{N_1}\right).$$

Figure 3 illustrates the application of this invention to the neutralization of capacity coupling between the primary and secondary circuits of a radio receiver. The arrangement of the apparatus in this figure embodies several features which tend to minimize capacity coupling, leaving relatively small capacity coupling to be directly neutralized, as described in detail below.

Reference character 1 indicates a metal lined cabinet containing the receiving apparatus and divided into compartments 2 and 3 by metal partition 4. This metal lining is grounded as at 5. The antenna 6 is connected thru the primary coil 7 of the coupler 8 and variable condenser 9 to the metal lining connected to earth 5. The antenna lead passes thru the metal walled cabinet but is insulated therefrom by insulator 10. The secondary coil L_1 of the coupler having terminals 12 and 13 is connected at one end thru lead 13^a with detecting apparatus in compartment 3 and at the other end to the metal lining 1 by means of lead 12^a. The lead 13^a passes thru partition 4 and is insulated therefrom by insulator 15. The detecting apparatus in compartment 3 may be composed of a suitable circuit inductance 16, variable condenser 17 grounded at 18 and leads 19 taken to the usual detector, preferably an audion. The moving elements of the condensers 9 and 17 are those connected to ground; so that no external capacity coupling effects will be present if the shafts of these moving elements extend thru the metal lining. The secondary coil L_1 is provided with auxiliary coil L_2 grounded at terminal 12 and free ended at terminal 21. This auxiliary coil is wound over secondary coil L_1 but in opposite direction thereto, from terminal 12 as a starting point.

By the arrangement of the apparatus as above described in compartments 2 and 3 it will be seen that the only possibility of capacity coupling between the primary and secondary circuits lies in the inherent capacities C_1 and C_3, between primary coil 7 and the secondary coil L_1. This capacity coupling is neutralized by the auxiliary coil L_2 and the inherent capacities C_2 and C_4 present by reason of the addition of coil L_2. In actual construction the turns of coil L_2 are wound over the turns of secondary coil L_1, giving close magnetic coupling and reducing the capacities C_1 and C_3 by their screening action. The circuit of Figure 3 is thus a special application of the general circuit of Figure 1, reference characters C_1, C_2, C_3, C_4, L_1 and L_2 corresponding identically, the primary coil 7 of Figure 3 corre-

sponding to the circuit element B of Figure 1, the portion of the secondary circuit in compartment 3 corresponding to the circuit element A, the antenna-ground circuit 6 to 5 corresponding to the impedance Z' and the arbitrarily variable condenser 9 corresponding to the impedance Z''. Neutralization of the capacity coupling will therefore be attained, as in Figure 1, when the capacity ratios C_1/C_2 and C_3/C_4 are made equal to the ratio of turns N_2/N_1 of the coils L_2 and L_1, respectively. The turns of L_2 are adjusted by trial and will be less than those on L_1 as the capacities C_2 and C_4 exceed C_1 and C_3 respectively. The symmetry of the arrangement is relied on to maintain approximate equality between C_1/C_2 and C_3/C_4, even when the coils L_1 and L_2 are moved relative to coil 7 to secure variations in electro-magnetic coupling between the primary and secondary circuits.

Figure 4 is a cross-sectional view showing the arrangement of the primary, secondary and auxiliary coupler coils 7, L_1 and L_2, respectively. The secondary coil has its high-potential end 13 connected through the secondary inductance 16 to the detecting apparatus as described and the auxiliary coil starts at the terminal 12 of the secondary coil and doubles back over the secondary coil in the opposite direction with the end 21 left free. The auxiliary coil is suitably supported over secondary coil L_1, by insulating drum 20. In case the lead 13^a from the upper terminal 13 of L_1 has appreciable capacity this may be neutralized by means of the arrangement shown in Fig. 8 wherein a dummy lead 21^a is shown connected to the terminal 21 of L_2 and disposed alongside of the lead 13^a. The alternative arrangement of Fig. 7 includes an additional auxiliary coil L'_2 wound inside the secondary coil L_1 the purpose of which is to provide more complete screening. Each of the coils L_1, L_2 and L'_2 is preferably grounded as shown at 12.

Figure 5 is a sectional view of the preferred arrangement of the coupling coils wherein the primary coil 7 is rigidly mounted on panel 22 by supports 23 and 24, secondary coil L_1 and auxiliary coil L_2 insulated therefrom by suitable insulation 20 are wound on frame 25 mounted on shaft 26 and capable of being rotated by means of knob 27 to obtain different degrees of coupling.

Figure 6 illustrates the application of this invention to the neutralization of the capacity coupling between the grid and plate circuits of an audion, the grid circuit containing a coil L_1 and the plate circuit an impedence Z. Reference character C_1 indicates the inherent coupling capacity, part of which is within the audion and part between the leads to the grid and the plate. To neutralize this capacity coupling, the auxiliary coil L_2 is closely coupled electromagnetically to the grid coil L_1 and is connected between the filament and the neutralizing capacity C_2 whose other terminal is connected to the plate. This circuit is a special application of the general circuit of Figure 2; and neutralization of the capacity coupling due to C_1 will be attained, as in Figure 2, when the ratio of capacities C_1/C_2 is made equal to the ratio of turns N_2/N_1 of the coils L_2 and L_1, respectively.

Figure 7 illustrates the application of this invention to the neutralization of the capacity coupling to the detector circuit of a high-frequency Wheatstone bridge. The detector is connected across the secondary coil L_1 of a transformer whose primary coil L'' is connected between the detector points of the bridge proper. The detector circuit is capacitively coupled to the bridge proper through the inherent capacities C_1 and C_3 and through the bridge arms and ground. To neutralize this capacity coupling the auxiliary coil L_2 is closely coupled electro-magnetically to L_1 and capacitively coupled to the bridge proper thru the neutralizing capacities C_2 and C_4. This circuit is a special application of the general circuit of Figure 1 and neutralization of the capacity coupling will be attained as in Figure 1, when the capacity ratios C_1/C_2 and C_3/C_4 are made equal to the ratio of turns N_2/N_1 of the coils L_2 and L_1, respectively. It is desirable to place the auxiliary coil L_2 between L'' and L_1, to reduce the capacities C_1 and C_3 by its screening action, as in Figure 4.

Having thus described my invention, what I claim and desire to secure by Letters Patent of the United States is:

1. In a system of two electric circuits coupled through a junction point and through a capacity, means for neutralizing the capacity coupling comprising a coil connected between said junction point and one terminal of said coupling capacity, and an auxiliary coil and a neutralizing capacity unequal to the coupling capacity connected between said junction point and the other terminal of the coupling capacity, said coils being closely coupled electromagnetically and having a ratio of turns equal to the inverse ratio of the capacities with which they are respectively associated.

2. In a system of two electric circuits in which an element of one circuit has one terminal connected to the second circuit through coupling impedances and has its other terminal connected to the second circuit through a group of coupling capacities, means for neutralizing said coupling comprising a coil connected between said terminals and an auxiliary coil closely coupled electromagnetically to the first coil and con-

nected between the first mentioned terminal and the common terminal of a group of neutralizing capacities, each of which extends to said second circuit, is associated with one coupling capacity, and has a ratio to its associated coupling capacity equal to the inverse ratio of turns of the auxiliary coil to the first coil.

3. In a system of two electric circuits in which an element of one circuit has one terminal connected to the second circuit through coupling impedances and has its other terminal connected to the second circuit through a pair of coupling capacities, means for neutralizing said coupling comprising a coil connected between said terminals and an auxiliary coil closely coupled electromagnetically to the first coil and connected between the first mentioned terminal and the common terminal of a pair of neutralizing capacities, each of which extends to said second circuit, is associated with one coupling capacity, and has a ratio to its associated coupling capacity equal to the inverse ratio of turns of the auxiliary coil to the first coil.

4. In a system of two electric circuits in which an element of one circuit has one terminal connected to the second circuit through arbitrarily variable coupling impedances and has its other terminal connected to the second circuit through a group of coupling capacities, means for neutralizing said coupling comprising a coil connected between said terminals and an auxiliary coil closely coupled electromagnetically to the first coil and connected between the first mentioned terminal and the common terminal of a group of neutralizing capacities, each of which extends to said second circuit, is associated with one coupling capacity, and has a ratio to its associated coupling capacity equal to the inverse ratio of turns of the auxiliary coil to the first coil.

5. An electric circuit arrangement for neutralizing capacity coupling between an electric circuit and an inductive coil comprising an auxiliary coil electro-magnetically coupled and connected to said coil with terminals of unlike polarity connected together, said auxiliary coil being interposed in the electro-static field created between said coil and said circuit.

6. In a wave signaling responsive device comprising a primary circuit and a secondary circuit the combination of a conducting screen electro-statically isolating the secondary from the primary circuits except for a pair of coupling coils and an auxiliary coil electro-magnetically coupled and connected to one of said coupling coils with terminals of unlike polarity connected together, said auxiliary coil having capacity coupling to the other of said coupling coils.

7. In a wave signaling responsive device comprising a primary circuit and a secondary circuit, the combination of a conducting screen electro-statically isolating the secondary from the primary circuits except for a pair of coupling coils, and an auxiliary coil electro-magnetically coupled and connected to one of said coupling coils with terminals of unlike polarity connected together, said auxiliary coil being interposed in the electro-static field created between said coupling coils.

LOUIS A. HAZELTINE.