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J. W. MILNOR ET AL

2,173,722

INTERFERENCE SUPPRESSION NETWORK

Filed Jan. 28, 1936

2 Sheets-Sheet 1

Fig. 1.

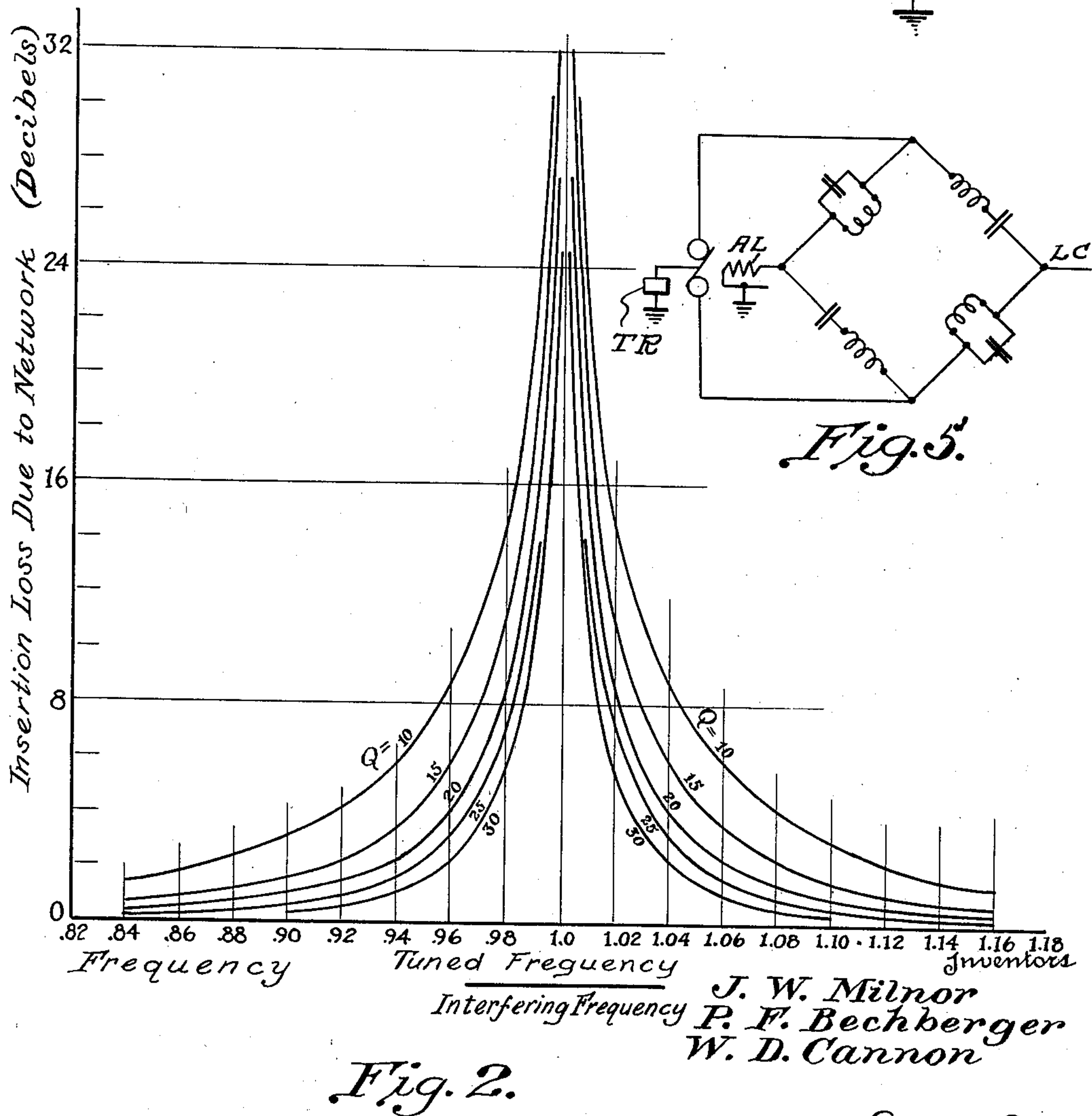
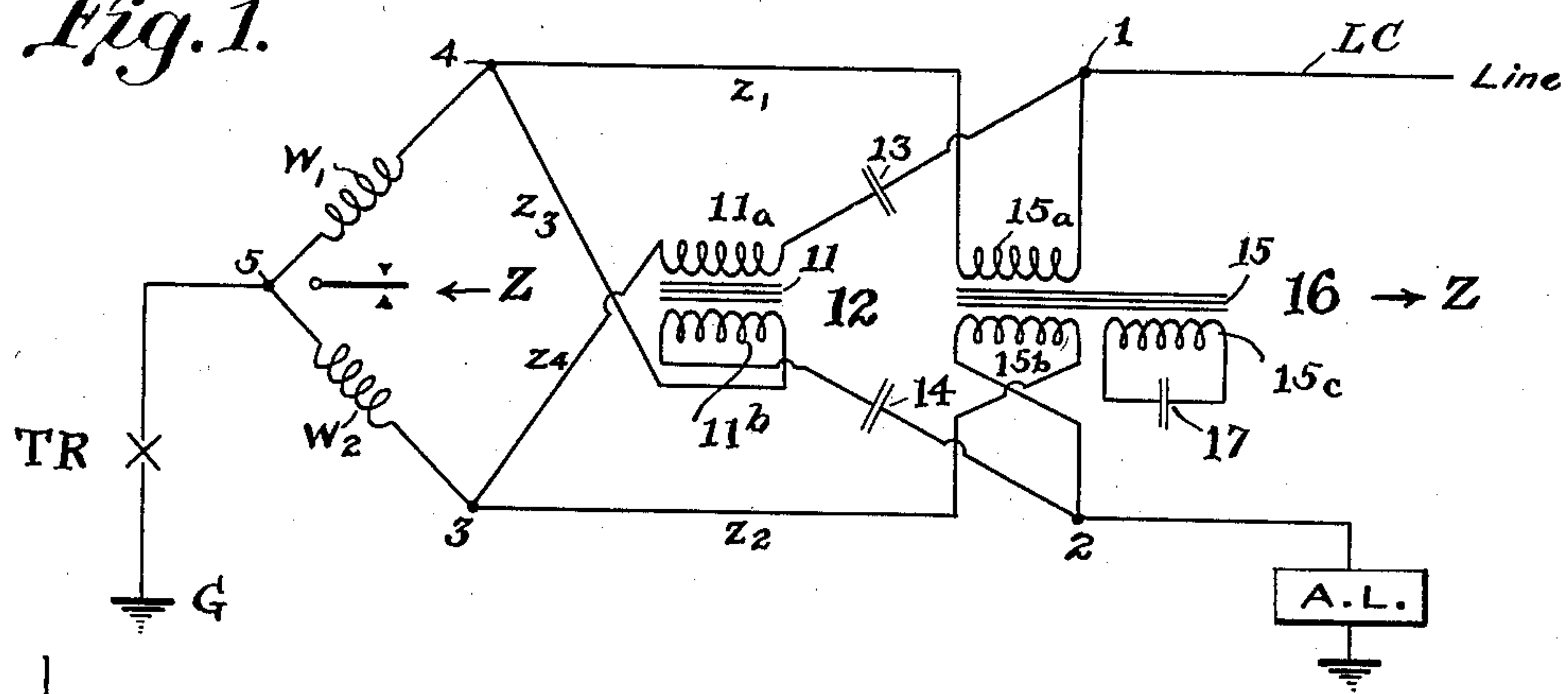


Fig. 2.

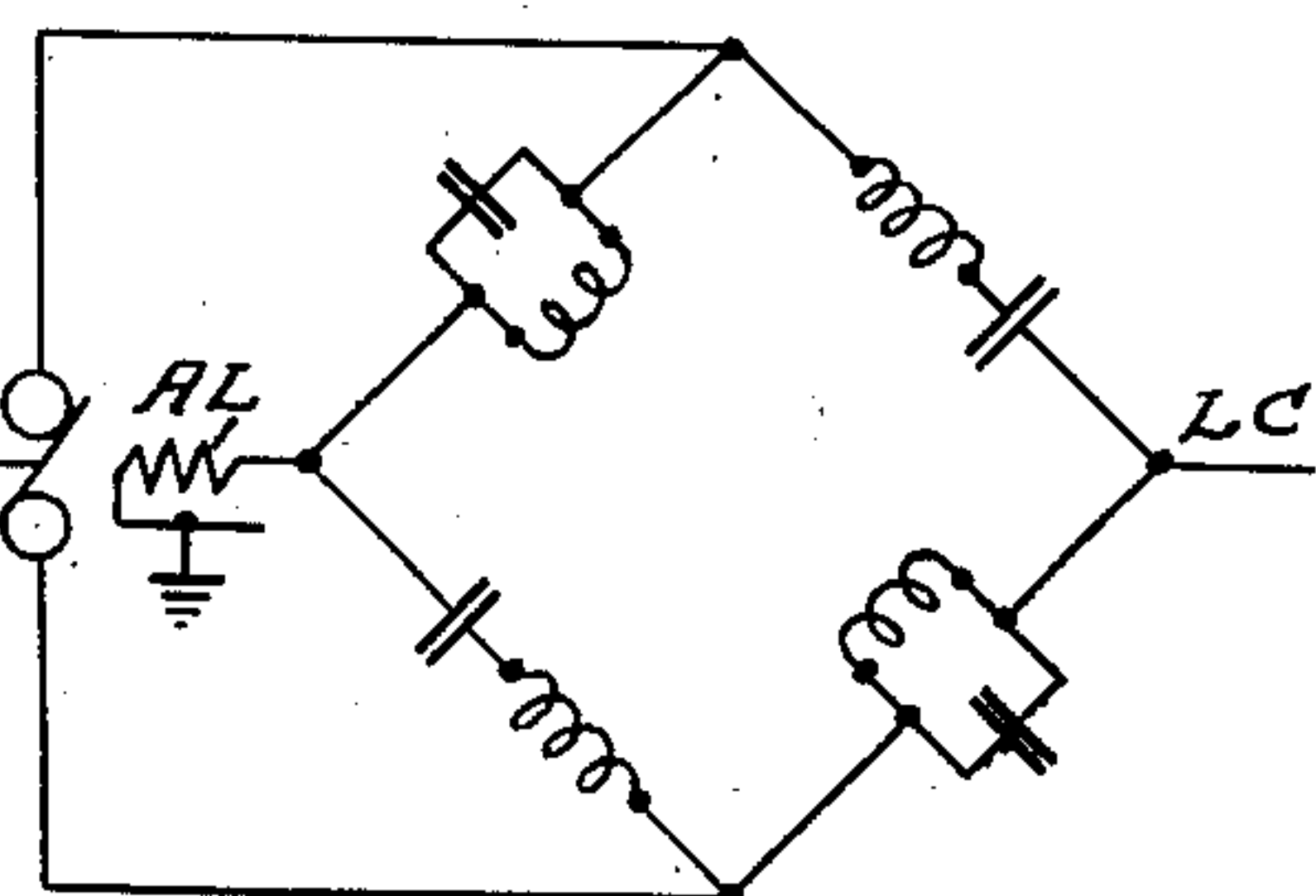


Fig. 5.

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2 Sheets-Sheet 2

Fig. 3.

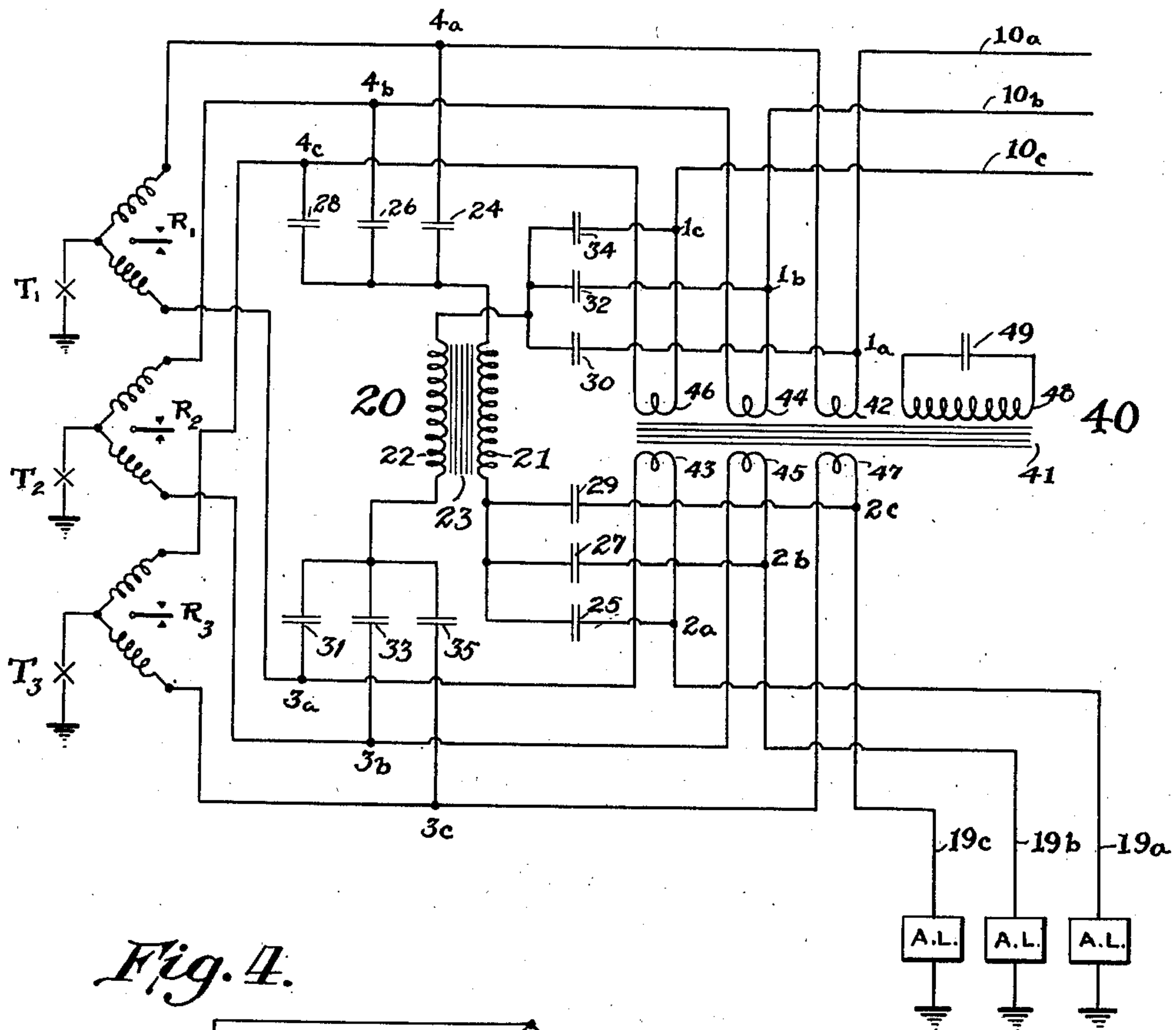
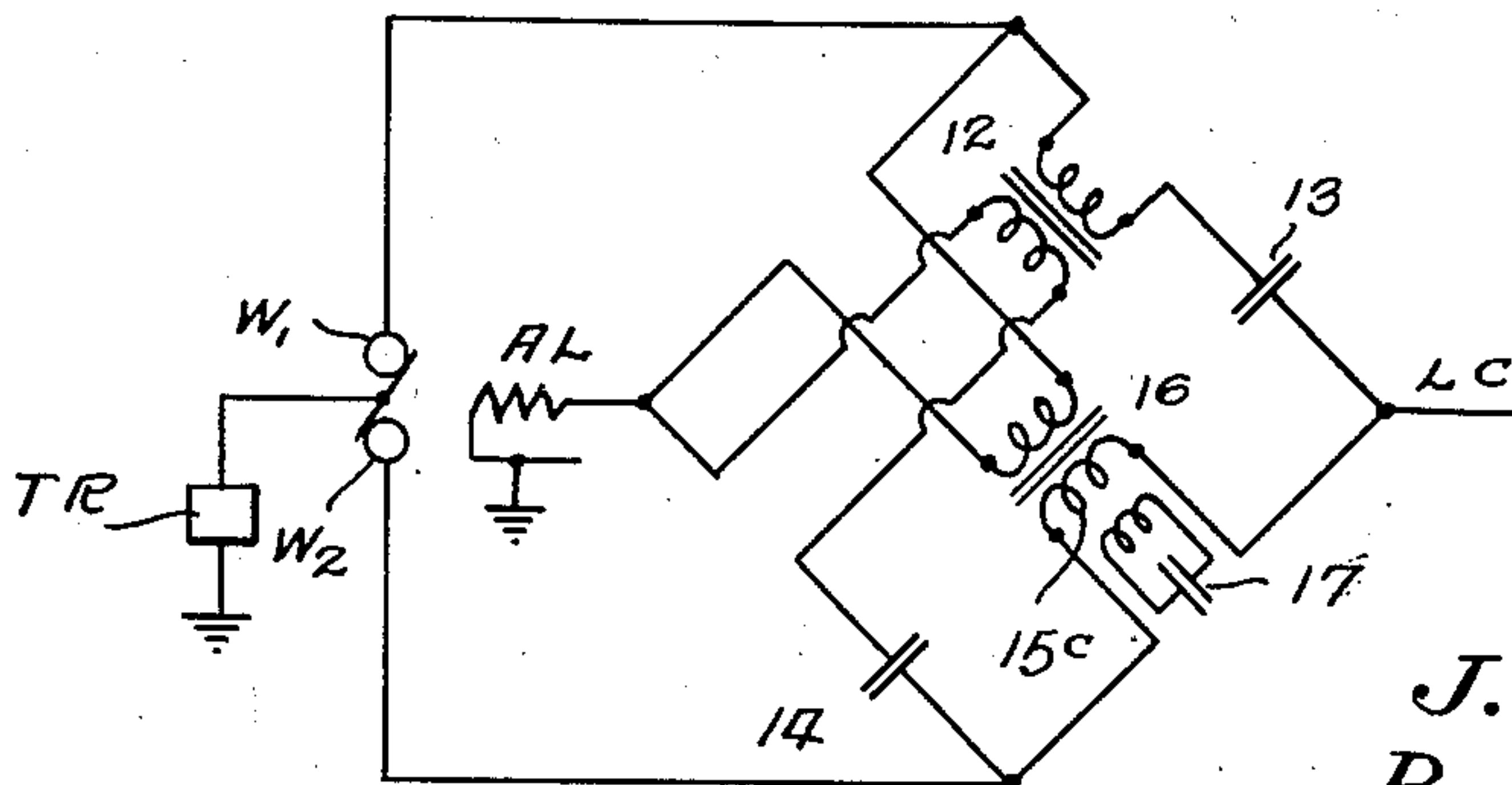


Fig. 4.



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INTERFERENCE SUPPRESSION NETWORK

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16 Claims. (Cl. 178—69)

This invention relates to an interference suppression network and in particular to a bridge type of interference suppression network adapted especially for application to duplex telegraph sets operating on grounded lines.

Broadly, the object of the invention is to provide means for excluding from the receiving relay circuit of a telegraph system disturbing currents induced into the line conductor by neighboring power or other interfering circuits. For accomplishing this purpose, specific objects of the invention are to provide a balanced bridge network composed of four tuned circuits, and in which one or both pairs of resonant opposite arms are mutually coupled, to provide a Wheatstone bridge network in which all the tuned arms have impedances equal at resonance and of the same order as the impedances of the line and terminal apparatus, to provide a balanced bridge tuned network in which a single tuned circuit is coupled to a plurality of arms so as to tune each of said arms to the disturbing frequency, to provide a balanced bridge network in which a single condenser serves to tune two arms of the bridge so as to provide circuits anti-resonant to the disturbing frequency.

The invention is applicable to a telegraph system comprising a plurality of duplex telegraph sets, and in this embodiment the object of the invention is to provide a single network of the type described which will be applicable to a plurality of lines, the network having the form of a plurality of Wheatstone bridges having certain elements in common.

Networks of the type of this invention in which all of the arms of the balanced bridge are formed of tuned circuits have the advantage that the efficiency of the network is considerably improved over that obtainable with networks of the types disclosed in Patents 1,773,371 and 1,766,919, in which combinations of resistances and tuned circuits are used. Furthermore, the use of common cores as disclosed in this invention avoid excessive bulk and unnecessary expense while still maintaining a high degree of efficiency in the elimination of power interference and preserving the balance of the telegraph sets.

The interference suppression network according to the invention has the characteristics of a Wheatstone bridge which is balanced at the frequency of the disturbing current, and unbalanced at signal frequencies. The receiver circuit being connected across the diagonal of the balanced bridge is in conjugate relation to the line conductor circuit for currents of the frequency

for which the bridge is balanced, and is, therefore, unaffected by currents of disturbing frequency incoming from the line. At the same time the lack of balance at signal frequencies makes the relay circuit receptive to incoming currents of signal frequencies, the effect of the network on these currents being only to introduce a negligible loss into the circuit.

By proper design of the network it has been possible to produce a direct current telegraph system operating at a dot frequency higher than an interfering frequency having a current magnitude of the same order or higher.

Referring to the drawings:

Figure 1 represents a duplex telegraph set with an interference suppression network designed in accordance with this invention;

Figure 2 shows a group of curves indicating the effect of the factor Q of the network in determining the overall performance of the device;

Figure 3 represents a telegraph system comprising three lines with a single interference suppression network connected to all three lines;

Figure 4 illustrates the circuit of Figure 1 arranged in a different manner for the purpose of explaining its operation;

Figure 5 is a simplified diagram illustrating the principles of the same circuit shown in the conventional form of a Wheatstone bridge.

In Figure 1 there is shown a duplex set of input impedance Z connected to a line of like impedance, with an interference suppressing network interposed between them. LC represents the line conductor over which telegraphic messages are to be received and transmitted. The line conductor is subject to disturbing current induced therein by neighboring power circuits or the like. The line is balanced by artificial line AL so as to render the transmitter TR and the receiver conjugate with respect to transmitted currents. The receiver is diagrammatically illustrated by windings W_1 and W_2 and an associated armature, the transmitter TR being connected between ground G and the junction point 5 of the receiver relay windings W_1 , W_2 . Terminals 1, 2, 3 and 4 are terminals of the interference suppression network. The line LC and artificial line AL are connected, respectively, to terminals 1 and 2. The ends of windings W_1 , W_2 remote from junction point 5 are connected to terminals 4 and 3.

The interference suppression network has four tuned arms; these arms will be identified hereinafter by the terminals of the network to which they are connected. Thus, the series resonant

arms are arms 1—3 and 2—4, while the anti-resonant arms are arms 1—4 and 2—3. In Fig. 1 each arm, 1—3 and 2—4 comprises the inductance of a coil 12 and the capacity of a tuning condenser. Coil 12 is composed of two windings 11a and 11b mounted on a common core 11. Condenser 13 in series with winding 11a of coil 12 forms the series resonant arm 1—3, while condenser 14 in series with winding 11b of coil 12 forms the opposite, series-resonant arm 2—4. The other pair of arms is composed of anti-resonant circuits including coil 16. Coil 16 is made up of three windings 15a, 15b and 15c on a common core 15, the third winding 15c of which is closed by condenser 17 to form a resonant circuit. Windings 15a and 15b of coil 16 are connected in arms 1—4 and 2—3 respectively, and by reason of the coupling provided by the common core 15 between the tuned circuit of winding 15c and the two arms, both arms are adjusted to anti-resonance for the disturbing frequency which is to be suppressed. The arms of the tuned network are so adjusted that they all have impedances equal at resonance and approximately equal to the impedances of the line and terminal apparatus. That is, if Z_1 , Z_2 , Z_3 and Z_4 represent the impedances of the four resonant arms of the network, as shown in Fig. 1, these impedances at resonance all have the same value and are approximately equal to the input impedance Z .

As is well known, this proportion of the elements of a Wheatstone bridge provides maximum sensitivity. At frequencies other than resonance the bridge is unbalanced, the degree of unbalance and consequent loss introduced being dependent upon the rigidity with which the values of the elements adhere to the requirements as set forth above.

The operation of the circuit arrangement illustrated in Figs. 1 and 4 is as follows:

The two tuned arms and the two anti-resonance arms are adjusted to resonance with the disturbing currents, which are usually alternating currents of 25 or 60 cycles frequency induced by neighboring power lines. Under the foregoing conditions, the bridge will be balanced with respect to disturbing currents and the receiving relay will not be operated thereby. However, for incoming telegraphic signals the bridge will not be balanced and signal currents will flow through the windings W_1 and W_2 of the relay and effect its operation. Upon transmitting signals from transmitter TR, the transmitted current flows through windings W_1 and W_2 in opposite directions and therefore the receiving relay will not be operated. Artificial line AL is adjusted in impedance to produce a balanced relation between transmitter TR and the receiving relay. In other words, transmitter TR is in conjugate relation with the receiving relay.

For the purpose of obtaining the desired values of resonant impedance the quality of the coils becomes important. This property can be represented by a factor Q equal to

$$\frac{2\pi fL}{R_{ac}}$$

where R_{ac} is the alternating current resistance of the coils. By making use of this factor, the requisite equality of the impedances of the arms is attained in the design of the network. A factor Q also exists for the network as a whole and it is this factor which determines the overall perform-

ance of the device. The effect of the circuit Q is indicated in the family of curves of Fig. 2.

In Fig. 2 the abscissae represent frequency, and the ordinates represent insertion loss due to the network. As shown in the figure, maximum loss occurs at frequency 1.0 which represents the interfering frequency. The curves represent the loss with frequency for different values of Q , the particular values of Q for which the curves are shown being represented as 10, 15, 20, 25 and 30. It can be seen that with coils of relatively high quality a very high degree of suppression of an interfering frequency is achieved.

Coils of high quality (large Q) at power frequencies are rather large in size. Furthermore, to construct a tuned network having separate inductances in the tuned arms would require inconveniently large values of condensers in the anti-resonant circuits. By combining the coils of arms 2—4 and 1—3 into a single coil 12, and the coils of arms 1—4 and 2—3 into a single coil 16 as shown in Fig. 1, the number of coils is halved and the large condensers of the anti-resonant circuits can be replaced by a single condenser 17 of the order of one microfarad. The total inductance of the two matched windings in series of the coil 15 should be

$$L = \frac{2ZQ}{2\pi f(1+Q^2)}$$

this Q being the Q for the circuit of the third winding. The inductance of this winding can be made such as to tune with a convenient value of capacity, and having also a maximum Q at the frequency to be rejected. The inductance of the two windings of coil 12 in series should be

$$L = \frac{2ZQ}{2\pi f}$$

Q here being applicable to the entire circuit.

The network described above is particularly effective for the suppression of power interference of 25 and 60 cycles. Satisfactory operation of duplex telegraph sets at speeds which closely approach the interfering frequency has been achieved. In fact it has been found possible to operate wires at speeds higher than the interfering frequency at only slightly reduced efficiency.

A still further economy in the use of this type of interference eliminating network can be achieved by adapting a single network to a plurality of wires. One method for doing this is shown in Figure 3 in which three lines are connected to a single network. The series coil contains separate windings for each line and for the associated artificial line connections, but in the diagonal coil a single winding serves for each of the three lines. The three lines are then isolated by means of the condensers.

Thus, in Fig. 3, three line conductors 10a, 10b and 10c are connected with their respective artificial lines through a network which forms a plurality of Wheatstone bridges one for each duplex telegraph set, the three bridges having the coils 20 and 40 in common. Each line has its own transmitter T_1 , T_2 or T_3 and its own receiver R_1 , R_2 or R_3 , represented diagrammatically by a pair of windings and an associated armature, in the same manner as shown in Fig. 1. The line is balanced in the usual manner so that signal current from a transmitter T_1 , T_2 or T_3 has no effect on the associated receiver R_1 , R_2 or R_3 . Between each line and artificial line is connected a Wheatstone bridge network designed according to this invention, the terminals of the network for line

10a and its artificial line connected to conductor 19a being 1a, 2a, 3a and 4a. Similarly, the network terminals for line conductor 10b are 1b, 2b, 3b and 4b and the network terminals for line conductor 10c are 1c, 2c, 3c and 4c.

Coil 20 has two windings 21, 22 mounted on a common core 23. The ends of winding 21 are connected to conductor 10a and its associated artificial line conductor 19a through the condensers 24 and 25, to form the series resonant arm 2a—4a, while the ends of winding 22 are connected to conductor 10a and its associated artificial line conductor 19a through condensers 30 and 31 to form opposite, series resonant arm 1a—3a. The arms 1a—3a and 2a—4a are mutually coupled through the core 23 of coil 20.

In similar manner coil 20 provides inductance for opposite arms 1b—3b and 2b—4b of the Wheatstone bridge connected to line conductor 10b and its associated artificial line conductor 19b. Winding 21 of coil 20 is connected to line 10b by condenser 26, and to conductor 19b by condenser 27 to form arm 2b—4b, while winding 22 of coil 20 is connected to line 10b by condenser 32 and to conductor 19b by condenser 33 to form arm 1b—3b. The arms 1b—3b and 2b—4b are mutually coupled through the core 23 of coil 20.

Similarly arm 2c—4c comprises condenser 28, winding 21 and condenser 29 in series while arm 1c—3c comprises condenser 34, winding 22 and condenser 35 in series.

It will be evident that the condensers 24, 26, 28 and 25, 27, 29 which serve to tune their respective bridge arms comprising winding 21 to resonance at the frequency which is to be suppressed, and condensers 30, 32, 34, and 31, 33, 35 which tune their respective bridge arms comprising winding 22 to resonance, also serve to isolate the three lines from one another.

Coil 40 has three sets of windings, one for each line conductor. The windings 42, 44 and 46 of coil 40 are connected to line conductors 10a, 10b and 10c respectively. The windings 43, 45, and 47 are connected to artificial line conductors 19a, 19b and 19c respectively. All six windings 42 to 47 inclusive are mounted on a common core 41, on which is also mounted a winding 48 which is closed through condenser 49. The circuit 48, 49 is so tuned that through the coupling of this tuned circuit to the windings 42, 43, 44, 45, 46, 47, each of these latter windings acts as an anti-resonant circuit to current of the frequency to be suppressed.

There are thus provided three pairs of anti-resonant arms, one pair for each line conductor and its associated artificial line. The opposite arms forming an anti-resonant pair for line 10a comprise winding 42 in arm 1a—4a and winding 43 in arm 2a—3a; for line 10b, winding 44 in arm 1b—4b and winding 45 in arm 2b—3b; for line 10c, winding 46 in arm 1c—4c and winding 47 in arm 2c—3c. These anti-resonant arms are all comprised in the single coil 40 and depend for their anti-resonant characteristic upon the common tuned circuit 48, 49.

Although it might seem that the group of lines would be subject to considerable interference due to coupling, this coupling is in fact negligible except at the resonant frequency. The separate condensers of the diagonal circuits are of the order of 0.1 mf., and since they are connected symmetrically between the lines and artificial lines, only a small amount of far end cross fire can result.

It would, of course, be possible, at somewhat greater cost, to provide a separate pair of windings on the diagonal transformer for each wire.

By arranging the cores 23 and 41 of coils 20 and 40 at right angles to one another interaction therebetween is prevented.

What we claim as our invention is:

1. In a telegraph system, the combination of a line conductor subject to disturbing current, a return path for said conductor, a receiver circuit which is to be protected from said disturbing current, a balanced bridge network connected between said line and said return path and to said receiver circuit, said bridge comprising two pairs of opposing arms, the two arms of one of said pairs comprising windings mounted on a common core, and a single means for tuning both said windings to anti-resonance at the disturbing frequency.

2. In a telegraph system, the combination of a line conductor subject to disturbing current, a return path for said conductor, a receiver circuit which is to be protected from said disturbing current, a balanced bridge network connected between said line and said return path and to said receiver circuit, said bridge comprising two pairs of opposing arms, the two arms of one of said pairs comprising windings mounted on a common core and individual condensers for tuning the windings to resonance at said disturbing frequency.

3. In a telegraph system, the combination of a line conductor subject to disturbing current, a return path for said conductor, a receiver circuit which is to be protected from said disturbing current, a balanced bridge network connected between said line and said return path and to said receiver circuit, said bridge comprising a pair of arms series resonant at the disturbing frequency and a second pair of arms comprising two windings of a transformer and means including a third winding of said transformer for tuning said transformer to the frequency of the disturbing current.

4. In a telegraph system, the combination of a line conductor subject to disturbing current, a return path for said conductor, a receiver circuit which is to be protected from said disturbing current, a balanced bridge network connected between said line and said return path and to said receiver circuit, said bridge comprising two pairs of opposing arms, the arms of one of said pairs comprising two windings of a three-winding transformer and a condenser connected across the third winding to tune the arms of said last mentioned pair to anti-resonance at the frequency of the disturbing current.

5. In a telegraph system, a plurality of line conductors subject to disturbing current, an artificial line balancing each of said conductors, a plurality of balanced bridges one for each line conductor connected between its line conductor and the corresponding artificial line, each bridge comprising four arms resonant at the frequency of the disturbing current, one of said arms comprising an impedance common to all of said balanced bridges.

6. In a telegraph system, a plurality of line conductors subject to disturbing current, an artificial line balancing each of said conductors, a plurality of balanced bridges one for each line conductor connected between its line conductor and the corresponding artificial line, each bridge comprising a pair of opposing arms series resonant at the frequency of said disturbing frequency.

quency, the anti-resonant arms of said bridges comprising windings mounted on a common core.

7. In a telegraph system, the combination of a plurality of line conductors subject to disturbing current, return paths for said line conductors, a single suppression network connected to all of said line conductors and said return paths so as to form a Wheatstone bridge connecting each line conductor and its return path and balanced at the frequency of said disturbing currents, said suppression network comprising impedance elements common to all said line conductors.

8. In a telegraph system, the combination of a plurality of line conductors subject to disturbing currents, return paths for said line conductors, a single suppression network connected to all of said line conductors and said return paths comprising a plurality of Wheatstone bridges one for each line conductor, said bridges comprising impedance elements common to said line conductors and other impedance elements individual to said line conductors.

9. In a telegraph system, the combination of a plurality of line conductors subject to disturbing currents, return paths for said line conductors, a Wheatstone bridge connected between each conductor and its return path balanced at the frequency of said disturbing currents, said bridges comprising a coil common to two arms of each bridge and common to all the bridges.

10. In a telegraph system, the combination of a plurality of line conductors subject to disturbing currents, return paths for said line conductors, a Wheatstone bridge connected between each conductor and its return path balanced at the frequency of said disturbing currents, said bridges comprising a coil having windings individual to the line conductors and their return paths but mounted on a common core and another winding mounted on said common core with means for tuning said other winding.

11. In a telegraph system the combination of a plurality of line conductors subject to disturbing currents, return paths for said line conductors, a Wheatstone bridge connected between each conductor and its return path balanced at the frequency of said disturbing currents, said bridges comprising a coil common to opposing arms of a pair in each bridge and common to all the bridges.

12. In a telegraph system the combination of a plurality of line conductors subject to disturbing currents, return paths for said line conductors, a Wheatstone bridge connected between each conductor and its return path balanced at

the frequency of said disturbing currents, said bridges comprising a coil common to all the bridges and condensers on each side of the coil symmetrically and individually connecting the coil to each line conductor and its return path.

13. In a duplex telegraph system, the combination of a line subject to disturbing current, an artificial line for balancing said line, and a balanced bridge network connected between said line and artificial line, said bridge comprising two pairs of opposing arms, the two arms of each pair being mutually coupled and resonant at the frequency of said disturbing current.

14. In a duplex telegraph system, the combination of a line conductor subject to disturbing current, an artificial line for balancing said line, a receiver circuit which is to be protected from said disturbing current and a bridge network connected between said line and artificial line and to said receiver circuit, said bridge comprising four impedance arms connected in lattice formation, two of said arms each including a parallel resonant circuit and the other two arms being constituted by series resonant circuits, the reactances of each of said four arms being resonant at a single frequency and suppressing a narrow range of frequencies while permitting a minimum attenuation at all other frequencies.

15. In a duplex telegraph system, the combination of a line conductor subject to disturbing current, an artificial line for balancing said line, a receiver circuit which is to be protected from said disturbing current, and a balanced bridge network connected between said line and artificial line and to said receiver circuit, said bridge comprising a pair of arms series resonant at the frequency of the disturbing current and a pair of arms anti-resonant at the said frequency, the arms of said first mentioned pair being mutually coupled.

16. In a duplex telegraph system, the combination of a line subject to disturbing current, an artificial line for balancing said line, and means for suppressing the range of frequencies included in the disturbing current, comprising a bridge network connected between said line and artificial line, said bridge having two pairs of opposing arms, each pair being resonant at the frequency of said disturbing current, the impedances of said arms being substantially equal at resonance and approximately equal either to the impedance of the line or to the impedance of the terminal apparatus.

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