

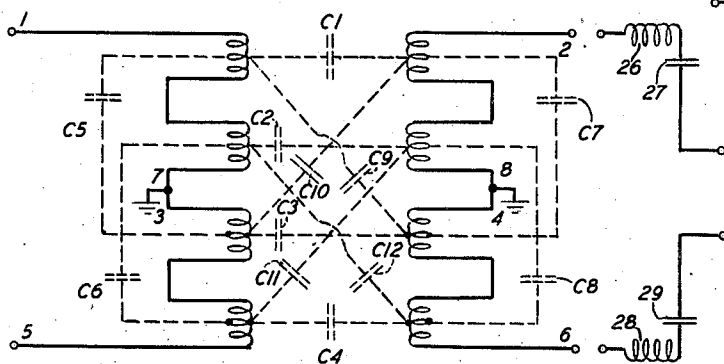
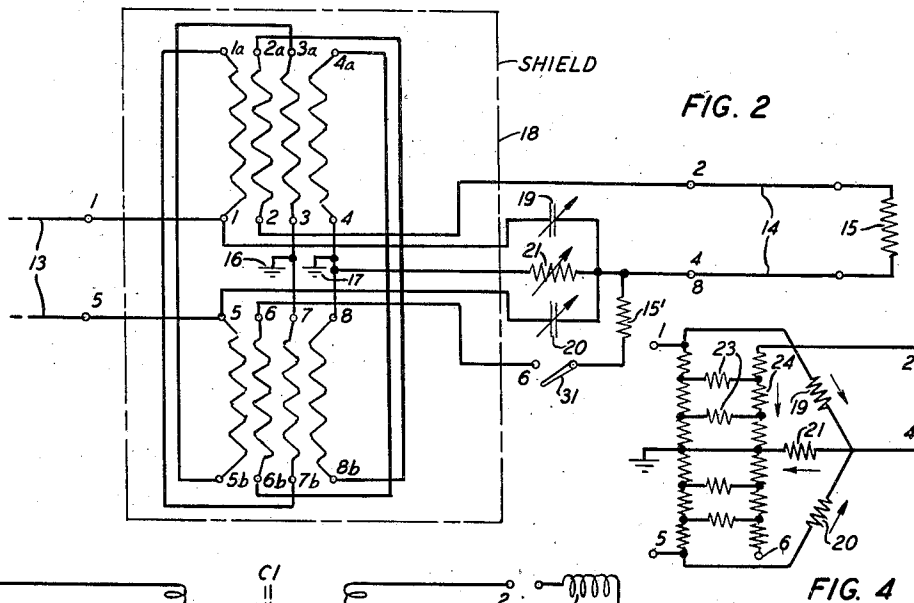
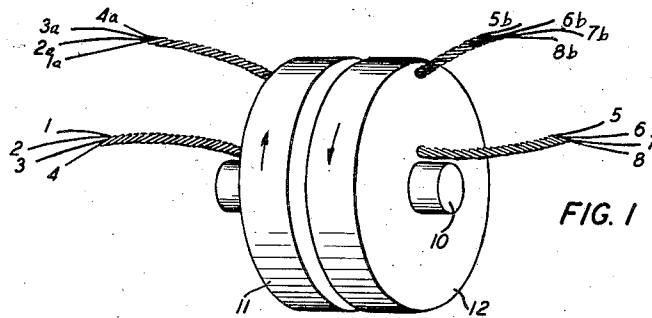
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TRANSFORMER

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TRANSFORMER

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4 Claims. (Cl. 178—44)

The present invention relates to a coupling network for transferring waves of a band of frequencies between circuits of different characteristic. More specifically, the invention may take the form of a multiwinding transformer of special construction to provide the desired band transmission characteristic but to minimize transfer from one circuit to the other of longitudinally transmitted currents.

A general object of the invention is a transformer network of the type indicated which will be economical to manufacture, will possess in practice a desired band characteristic and will prevent to a high degree the transmission of longitudinal currents.

Such longitudinally transmitted currents, it will be understood, are caused by interference from neighboring power lines, lightning or other sources and these currents flow along both line wires in parallel to ground.

It has been common practice heretofore to minimize transfer of the longitudinal currents by providing a winding arrangement such as to balance the windings and the interwinding capacities and further to employ a grounded electrostatic shield between primary and secondary windings. While it has been possible by these means to achieve a high degree of shielding against the longitudinally transmitted currents, these types of coils are relatively expensive to build.

Applicant conceived that if the interwinding shield could be dispensed with entirely, an item of relatively high cost could be eliminated. It is easy to make a coil with highly symmetrical windings and very close coupling by making the winding of a quad of intimately twisted wires. Such a coil can be wound on a standard winding machine. The individual wires can then be connected in such order in the windings as to provide a high degree of symmetry. Instead of inserting an interwinding shield, which in a winding of this type would require the use of shielded pairs, would be expensive and would lead to several difficulties, applicant provides an external balance by use of adjustable capacities which can be balanced to produce a differential or bridge connection that suppresses transmission of the longitudinal currents to a high degree. This construction can be used in the case of air core or magnetic core coils either open or shell type but will be disclosed specifically as embodied in an air core coil.

The nature of the invention and its objects and features will appear more fully from the

following detailed description of an illustrative or typical embodiment as shown in the drawing, in which

Fig. 1 shows in perspective the general shape and disposition of the windings as seen externally;

Fig. 2 is a diagram showing how the windings are composed and their sections interconnected and how the coil is inserted in a line;

Fig. 3 is a diagram to show the symmetry of the coil and principal internal capacitances; and

Fig. 4 is an impedance or admittance diagram to show direction of current flow in the neutralizing circuit.

While, as already noted, the invention may be embodied in a variety of forms, one coil constructed and used by applicant was of the form shown in Fig. 1 where the two coils 11 and 12 were mounted side by side on a non-magnetic support 10. Each coil 11, 12 is made by winding a twisted quad, the directions of winding being opposite as denoted by the arrows. The inner ends of the wires of the quad in the case of coil 11 are numbered 1, 2, 3 and 4 and the inner ends of the quad in the case of coil 12 are numbered 5, 6, 7 and 8. The corresponding outer ends are numbered 1a, 2a, 3a and 4a and 5b, 6b, 7b and 8b, respectively. For illustration, in one embodiment each coil was 1 inch wide and 4 inches in diameter and the support 10 was 1 inch in diameter. Each quad consisted of four No. 24 double cotton-covered copper wires twisted together throughout their length. This coil was for use in the frequency range 5 kilocycles to 30 kilocycles. The entire coil is placed within a copper shield indicated in Fig. 2 but omitted from Fig. 1.

Fig. 2 shows the manner of interconnecting the individual conductors to make up the primary winding, connected between terminals 1 and 5, and the secondary winding, whose terminals are 2 and 6. Incoming line 13 which is balanced to ground is connected to terminals 1 and 5 while outgoing line 14, which is unbalanced to ground, is connected to terminals 2 and 4 (which is also terminal 8). In this case terminal 6 is left open. Line 14 has a suitable load impedance 15. The center of the primary winding is grounded at 16. Tracing through this winding from terminals 1 to 5, the order of connection is 1, 1a, 7b, 7, ground 16, 3, 3a, 5b, 5. Tracing through the secondary winding from terminals 2 to 6, the order of connection is 2, 2a, 8b, 8, 17 (ground) 4, 4a, 6b, 6. The entire structure is placed within shield 18.

The adjustable capacities 19, 20 and resistance 21 are for the purpose of balancing out residual admittance to longitudinal currents between primary and secondary terminals, and their use for this purpose will be explained more fully after reference has been made to the capacity distribution diagram of Fig. 5.

The effect of the interwinding admittances on longitudinal currents can be explained most readily by tracing the path of the longitudinal currents flowing into the two line terminals 1 and 5 in equal amounts. Since terminals 1 and 5 are both at the same potential and the inductances and admittances are balanced by design and adjustment, the currents will flow from terminal 1 towards 7 and from 5 towards 3 to reach ground. Since these currents are flowing in opposite directions in the primary winding and the couplings are such that the mutual impedances are balanced, there will be no resultant voltage induced magnetically in the secondary winding and, since the two halves of the primary winding are closely coupled because of the winding arrangement, there will be very little impedance to the flow of these longitudinal currents to ground, the only impedance being that of the direct current resistance of the primary winding and the small leakage between the twisted wires of the quad. The voltage drop of the longitudinal currents across the direct current resistance and leakage reactance will result in a residual longitudinal difference of potential between terminals 1 or 5 and ground with correspondingly lower potentials along the winding as we approach the grounded mid-point. These residual longitudinal potentials will result in a current flow through admittances $C_1, C_2, C_3, C_4, C_9, C_{10}, C_{11}$ and C_{12} . These capacitances can be paired as regards their transfer admittance for longitudinal currents. For example, C_1 and C_4 have opposite effects since they couple to winding sections in the secondary that are oppositely connected with respect to ground. This can be seen from noting that the capacity current through C_1 in seeking ground flows in the direction of 2 to 2a whereas that through C_4 flows in the direction 6 to 6b. These tend to nullify each other in view of the close coupling between turns and symmetry of windings. In the same way the other capacities tend to balance out in pairs as regards the longitudinal currents. Due to the close coupling between sections of the secondary winding which minimizes the impedance to ground there is no voltage drop between terminals 2 or 6 and ground from these admittance currents except for the drop of potential due to the non-inductive resistance of the windings.

To illustrate how this small voltage drop due to the resistive component can be balanced out by the elements 19, 20 and 21 of Fig. 2 in accordance with the invention, the admittance diagram of Fig. 4 is first referred to, in which the admittances are shown as resistances without attempting to represent each in individual detail but rather giving the general pattern. Longitudinal currents from terminals 1 and 5 seeking ground flow in part across the admittances 23 and downward through admittance 24 to ground as shown by the arrow. The drop in potential caused by this current flowing through impedance 24 raises the potential of terminal 2 above ground by the amount of this drop. To offset this, additional admittance currents from terminals 1 and 5 are allowed to flow through admittances 19 and 20, and through the resistor

21 to ground in the direction of the arrow. Such current in flowing to ground raises the potential of terminal 4 above ground by the same amount that terminal 2 was raised so that there exists no resultant difference of potential between terminals 2 and 4 as a result of the flow of longitudinal currents. Hence there will be no resultant current in the load connected between 2 and 4.

Referring to Fig. 2, it is seen that the provision of adjustable condensers 19 and 20 supplies the corresponding admittances of Fig. 4 and enables a high degree of suppression of the longitudinal currents. The best adjustment of the elements 19, 20, 21 can be determined by trial by applying between the terminals 1 and 5 in parallel and ground a voltage of the highest frequency of interest and adjusting the elements 19, 20 and 21 to secure minimum secondary current between terminals 2 and 8 when properly terminated.

Referring again to Fig. 3, it will be noted capacities C_5 and C_6 are in shunt relation to the primary winding and similarly capacities C_7 and C_8 appear in shunt relation to the secondary winding. These capacities tend to impair the transmission of high frequencies. This tendency may be counteracted by including in series with the primary or secondary or with both a suitable amount of inductance indicated in Fig. 3 as inductance 26 in series with the secondary circuit of sufficient amount to nullify the effective negative reactance obtained when measuring the load impedance through the transformer. A similar inductance 28 may be associated with terminal 6 if that terminal is used.

In the case of an air core coil the mutual inductance may be smaller than desired and the shunting effect of this comparatively low mutual inductance may be compensated for by placing a condenser in series with the primary circuit or the secondary circuit or both, such capacity being of sufficient magnitude to cancel the reactive component of the input impedance at the lowest operating frequency when the transformer is terminated in its proper load impedance. Such a series condenser is indicated in Fig. 3 at 27 or 29.

At the mid-frequency in the transmitted band the shunt admittance composed of capacities C_5, C_6, C_7 and C_8 tend to antiresonate the shunt inductance making the shunt impedance a very high effective resistance. At the same time the added series inductance 26, 28 can be made to resonate with the added series condenser 27, 29 to produce an effective series reactance which is substantially zero at the mid-frequency of the band.

While in Fig. 2 the line 14 is shown as an unbalanced line connected between terminal 2 and ground, the coil disclosed is equally applicable for connecting two balanced lines, or a balanced line and a balanced load. For example, a load 15' can be connected between terminals 6 and 4 by closure of switch 31, load 15' being similar in impedance to load 15.

As noted above the invention may be embodied in various types of transformer construction either with or without magnetic cores and is not therefore to be construed as limited to the particular forms illustrated but the scope of the invention is defined in the claims.

What is claimed is:

1. A two-winding transformer for coupling a first circuit that is balanced with respect to ground to a second circuit that is unbalanced with

respect to ground, said transformer comprising closely coupled sectionalized and interleaved windings with alternate sections wound in opposite directions and with the interwinding capacitances arranged to provide a substantial balance for preventing transmission of the longitudinal currents, said first circuit being connected to opposite terminals of one winding with its center point connected to ground, said second circuit being connected between one terminal of the other winding and ground, a resistance included in the grounded side of said second circuit and a pair of balancing condensers connected between respectively opposite terminals of said one winding and the ungrounded end of said resistance and forming with said resistance a balancing circuit for further balancing out the longitudinal current in the second circuit.

2. A transformer comprising one winding section formed of a twisted quad, a second winding section mounted adjacent to said one winding section and formed of a twisted quad wound oppositely with respect to the first-mentioned winding section, a primary winding made up of certain wires of each quad joined end to end, a secondary winding made up of other wires of each quad similarly joined, whereby closely coupled symmetrical windings are obtained, an incoming circuit balanced with respect to ground connected across said primary winding, an outgoing circuit unbalanced with respect to ground connected across one half of said secondary winding, a series impedance in said outgoing circuit and a pair of condensers connected between opposite points of said primary winding and said impedance for opposing flow in said outgoing circuit of current transferred through said transformer from a circuit consisting of the two sides of said incoming circuit in parallel and ground.

3. A transformer comprising a sectionalized primary winding and a sectionalized secondary winding, alternate sections of the primary winding consisting of respective conductors intimately twisted with each other and with the conductors

forming alternate sections of the secondary winding, whereby close coupling and a high degree of symmetry are obtained, a center tap of each winding connected to ground, a balanced transmission line connected to outer terminals of the primary winding, an unbalanced circuit connected between an outer terminal of the secondary winding and the grounded center tap, a resistance in the side of said unbalanced circuit connected to said center tap, and a pair of capacitors connected from the ungrounded end of said resistance to opposite points of said primary winding for directly transferring to said resistance from said balanced line a voltage component of proper magnitude and sign to cancel the voltage component set up in said unbalanced circuit through couplings due to the interwinding capacities of said transformer from the voltage existing between the two sides of said balanced line in parallel and ground.

4. A transformer comprising one winding section formed of a twisted quad, a second winding section mounted adjacent to said one winding section and formed of a twisted quad wound oppositely with respect to the first-mentioned winding section, a primary winding made up of certain wires of each quad joined end to end, a secondary winding made up of other wires of each quad similarly joined, whereby closely coupled symmetrical windings are obtained, said primary winding and said secondary winding each having a center tap adapted to be connected to ground, a balanced transmission line connected to the outer terminals of said primary winding, balanced load impedances connected to the outer terminals of said secondary winding, said load impedances having a common terminal, a resistance connected between said common terminal and the center tap of said secondary winding, and a pair of condensers connected from respective terminals of said primary winding to the end of said resistance adjacent said common load terminal.

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