

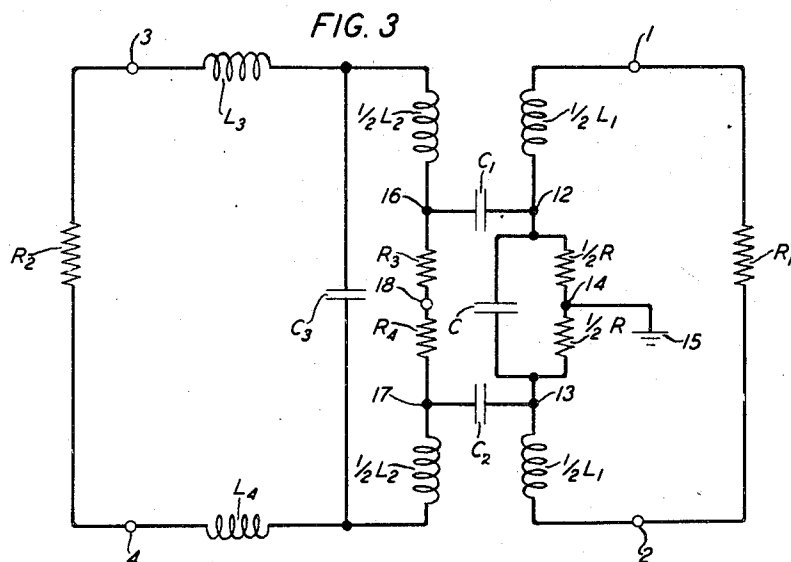
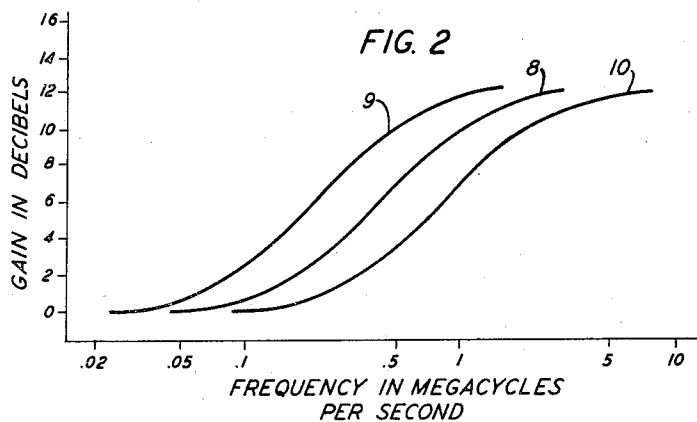
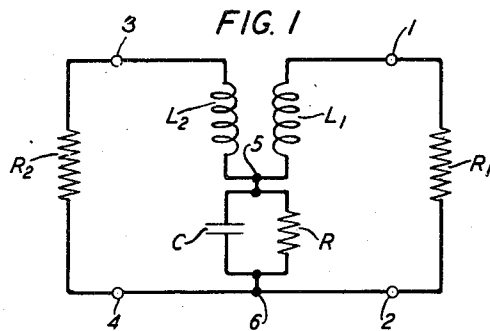
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COUPLING NETWORK

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COUPLING NETWORK

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This invention relates to wave transmission networks and more particularly to a network for coupling two unequal load impedances.

An object of the invention is to connect two loads of unequal impedance.

Other objects are to widen the band transmitted by a network for coupling unequal load impedances, reduce the transmission loss in the higher frequency range and minimize the phase shift introduced by such a network and reduce the reflection effects at the point of juncture between the network and the load.

In a wave transmission system, it is often required to connect together two unequal load impedances while introducing the minimum of high frequency transmission loss, phase shift and impedance mismatch. Heretofore, it has been difficult to accomplish these objectives, especially if the system is to transmit a wide band of frequencies such, for example, as is employed in television.

In accordance with the invention, there is provided a coupling network of comparatively simple structure which will meet all of the requirements set forth. The network comprises two inductively coupled inductors, connected in the series-opposing relationship in an electrical path between the two unequal load impedances, and an impedance branch including a capacitor and a resistor in parallel, connected from a point between the inductors to a point in a second electrical path between the load impedances. In the lower frequency range, where the impedance of the inductors is low and the impedance of the capacitor is high, the network functions as a resistance coupling. In the higher frequency range, where the impedance of the capacitor is low compared to that of the resistor, the network acts as a transformer coupling. The elements may be so proportioned that one of the loads is terminated in an impedance which is substantially matching over the entire frequency range.

As compared to a simple resistance coupling the network provides a transmission gain which increases with frequency, at first more rapidly and later less rapidly. The frequency range covered depends upon the choice of values for the inductors and the capacitor.

The network may be constructed in either the balanced or the unbalanced form. Blocking capacitors may be added between the coupled inductors to prevent the passage of direct current. In order to annul the effects of the leakage inductance and the stray capacitances, a shunt capacitor may be added to provide a low-pass

filter section. To annul the effect of a negative reactive component which may be associated with one of the load impedances a series inductor may be added to form another low-pass filter section.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing in which like reference characters represent like or similar parts and in which:

Fig. 1 is a schematic circuit of a coupling network in accordance with the invention;

Fig. 2 shows a family of curves representing the transmission gain introduced by the network, as compared to a resistance coupling; and

Fig. 3 is a schematic circuit of the coupling network in balanced form.

Taking up the figures in more detail, Fig. 1 shows one embodiment of the coupling network of the invention in its unbalanced form. The impedances R_1 and R_2 connected respectively to the two pairs of terminals 1, 2 and 3, 4 represent the unequal loads which are to be connected together. The load R_1 may, for example, be a transmission line or other utilization circuit and R_2 may be an amplifier or other terminal apparatus, the impedance of which is higher than that of the load R_1 . In an electrical path between the terminals 1 and 3 are two closely coupled inductors L_1 and L_2 connected in the series-opposing relationship. Connected from a point 5 between the inductors L_1 and L_2 to a point 6 in an electrical path between the terminals 2 and 4 is an impedance branch comprising a resistor R and a capacitor C in parallel.

In order to avoid reflection effects at the junction of the line or other load R_1 and the network, it is desirable that the load R_1 be terminated in a matching impedance. At low frequencies the impedance of the inductors L_1 and L_2 will be small and the impedance of the capacitor C will be large, leaving the shunt resistor R as the only effective impedance. The resistor R is, therefore, given such a value that, in parallel with the load R_2 , the combination will have an impedance equal to R_1 . Assuming that the impedances R_1 and R_2 are non-reactive, the required value of the resistance of R is found from the equation:

$$R = \frac{R_1 R_2}{R_2 - R_1} \quad (1)$$

When R has this value, the impedance of the network at the terminals 1 and 2 will be equal to R_1 and, therefore, the load R_1 will be termi-

nated in its own impedance in the low frequency range.

At high frequencies the impedance of the capacitor C is small and the resistor R is effectively shunted out, leaving only the transformer action of the inductors L_1 and L_2 . For proper impedance matching the inductances of L_1 and L_2 should, therefore, have the same ratio as that of the loads R_1 and R_2 . Assuming perfect coupling between the inductors,

$$\frac{L_1}{L_2} = \frac{R_1}{R_2} \quad (2)$$

If the inductors L_1 and L_2 have this ratio, the impedance of the network at the terminals 1 and 2 will be equal to R_1 over the high frequency range.

If the capacitance of the capacitor C is properly chosen, the network will also have an impedance at the terminals 1 and 2 which is approximately equal to R_1 over the intermediate frequency range. The required value of C is given by the equation

$$C = \frac{L_1 \left(\sqrt{\frac{R_2}{R_1}} - 1 \right)^2}{R_1 R_2} \quad (3)$$

If the elements C, R, L_1 and L_2 are proportioned in accordance with Equations 1, 2 and 3 the impedance of the network at the terminals 1 and 2 will be equal to R_1 over the entire frequency range transmitted and consequently the load R_1 will be properly terminated for the reflectionless transmission of energy. Leakage inductance and stray capacitances may cause this impedance to depart somewhat from R_1 but these may be compensated to a large extent by the means hereinafter described.

The only factor yet to be determined is the inductance of the inductor L_1 , the choice of which depends upon the frequency range to be covered. The curves of Fig. 2 show on a logarithmic frequency scale, the transmission gain in decibels resulting from the insertion of the coupling network of Fig. 1, as compared with the insertion of only the shunt resistor R. Curve 8 represents this gain if L_1 has a certain value. The curve rises with frequency, at first more and then less rapidly. If L_1 is doubled, for example, the gain characteristic will be as shown by curve 9, and if L_1 is halved curve 10 will result. It is seen, therefore, that by properly choosing the value of L_1 any one of an infinite family of gain characteristics may be obtained. In practice L_1 may often be so chosen that the resulting gain characteristic serves to equalize to a large extent for attenuation distortion in other parts of the system such, for example, as an associated transmission line. It should be pointed out, further, that the coupling network of Fig. 1 introduces the minimum phase shift that it is possible to associate with a given insertion loss characteristic.

The schematic circuit of Fig. 3 shows a balanced form of the coupling network of the invention. Here the load R_2 may, for example, include the plate impedances or the grid impedances of two thermionic tubes connected in series and working push-pull. These tube impedances are ordinarily shunted by a resistance to reduce and stabilize the impedance R_2 .

As shown in Fig. 3 each of the windings L_1 and L_2 of the transformer is divided into two equal parts. Between the inner terminals 12 and 13 of the two halves of L_1 is connected the impedance branch comprising the capacitor C shunted by a

resistance of value R tapped at its mid-point 14 and grounded as shown at 15. Two equal resistors R_3 and R_4 , of comparatively high resistance, are connected between the inner terminals 16 and 17 of the two halves of L_2 . These resistors have a common terminal 18 which may be used, for example, in supplying plate current to the tubes included in the load R_2 .

Terminals 12 and 16 are connected through a capacitor C_1 and terminals 13 and 17 are connected through a capacitor C_2 . These capacitors have large capacitances and their function is to provide a low impedance path at high frequencies but to prevent the flow of direct current through the network.

The shunt capacitor C_3 is proportioned with respect to the leakage inductance of the coupled inductors and the associated stray capacitances to form a low-pass filter section with cut-off above the highest frequency to be transmitted by the network. The two equal series inductors L_3 and L_4 are proportioned with respect to the negative reactive component associated with the load R_2 to provide a second low-pass filter section also having a cut-off above the highest frequency of interest. These filter sections are so designed that their image impedances approximate the impedance R_2 over the transmitted range.

These added elements C_3 , L_3 and L_4 serve to make the impedance of the network at terminals 1 and 2 more nearly constant and more nearly a pure resistance over a wide frequency range. This range may, under some circumstances, be extended by the addition of another shunt capacitor connected between terminals 1 and 2 and proportioned in the same manner as C_3 to provide additional leakage balancing. The coupling network of Fig. 3 may be designed to transmit satisfactorily the broad band of frequencies used in television, extending, for example, from 30 cycles or lower to 5 megacycles or higher. When used in television circuits the minimum phase shift property of the network, already mentioned, is of considerable importance as it materially simplifies the problem of phase correction.

What is claimed is:

1. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled inductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, the inductance ratio of said inductors being approximately equal to the ratio of said load impedances.

2. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, said resistor having a resistance approximately equal to the product of said load impedances divided by the difference of said impedances.

3. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor

and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, the capacitance C of said capacitor having approximately the value

$$C = \frac{L \left(\sqrt{\frac{R_2}{R_1}} - 1 \right)^2}{R_1 R_2}$$

where L is the inductance of one of said inductors and R_1 and R_2 are the respective values of said load impedances.

4. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, the capacitance of said capacitor being so proportioned with respect to the inductance of one of said inductors and the values of said load impedances that the network has at one end an impedance which, over a wide range of frequencies, is approximately equal to the load impedance at that end.

5. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, said resistor having a resistance approximately equal to the product of said load impedances divided by the difference of said impedances and the inductance ratio of said inductors being approximately equal to the ratio of said impedances.

6. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, said resistor having a resistance approximately equal to the product of said load impedances divided by the difference of said impedances and the capacitance of said capacitor being so proportioned with respect to the inductance of one of said inductors and the values of said load impedances that the network has at one end an impedance which is approximately equal to the load impedance at that end.

7. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, the inductance ratio of said inductors being approximately equal to the ratio of said load impedances and the capacitance of said capacitor being so proportioned with respect to the inductance of one of said inductors and the values of said load impedances that the network has at one end an impedance which is approximately equal to the load impedance at that end.

8. A network for coupling two unequal load

impedances comprising two electrical paths adapted to interconnect said impedances, two inductively coupled conductors connected in the series-opposing relationship in one of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said inductors to a point in said other path, said resistor having a resistance approximately equal to the product of said load impedances divided by the difference of said impedances, the inductance ratio of said inductors being approximately equal to the ratio of said impedances and the capacitance of said capacitor being so proportioned with respect to the inductance of one of said inductors and the values of said load impedances that the network has at one end an impedance approximately equal to the load impedance at that end.

9. A network in accordance with claim 1 and an added capacitor connected in shunt at one end of the network, the capacitance of said added capacitor being proportioned with respect to the leakage inductance of said inductors and the stray capacitances to provide a low-pass filter having a cut-off above the highest frequency to be transmitted by the network.

10. A network in accordance with claim 1 in which inductance is added in series with one of said inductors, the value of said inductance being proportioned with respect to a negative reactive component associated with one of said load impedances to provide a low-pass filter having a cut-off above the highest frequency to be transmitted by the network.

11. A network in accordance with claim 1 which includes an added capacitor connected in shunt at one end of said network and added inductance in series with one of said inductors, the capacitance of said added capacitor being proportioned with respect to the leakage inductance of said coupled inductors and the stray capacitances, and the value of said added inductance being proportioned with respect to a negative reactive component associated with one of said load impedances, to provide a low-pass filter having a cut-off above the highest frequency to be transmitted by the network.

12. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, a pair of inductively coupled inductors connected in the series-opposing relationship in one of said paths, a second similar pair of inductors similarly connected in the other of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said first pair of inductors to a point in said other path between said second pair of inductors, the inductance ratio of the inductors forming each of said pairs being approximately equal to the ratio of said load impedances.

13. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, a pair of inductively coupled inductors connected in the series-opposing relationship in one of said paths, a second similar pair of inductors similarly connected in the other of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said first pair of inductors to a point in said other path between said second pair of inductors, said resistor having a resistance approximately equal to the product of said load im-

pedances divided by the difference of said impedances.

14. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, a pair of inductively coupled inductors connected in the series-opposing relationship in one of said paths, a second similar pair of inductors similarly connected in the other of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said first pair of inductors to a point in said other path between said second pair of inductors, the capacitance of said capacitor being so proportioned with respect to the inductance of one of said inductors and the values of said load impedances that the network has at one end an impedance which, over a wide range of frequencies, is approximately equal to the load impedance at that end.

15. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, a pair of inductively coupled inductors connected in the series-opposing relationship in one of said paths, a second similar pair of inductors similarly connected in the other of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said first pair of inductors to a point in said other path between said second pair of inductors, the two inductors in each of said pairs being connected through an added capacitor.

16. A network for coupling two unequal load impedances comprising two electrical paths adapted to interconnect said impedances, a pair of inductively coupled inductors connected in the series-opposing relationship in one of said paths, a second similar pair of inductors similarly connected in the other of said paths and an impedance branch including a capacitor and a resistor in parallel connected from a point in said one path between said first pair of inductors to a point in said other path between said second pair of inductors, an inductor in one of said pairs being connected to an inductor in the other of said pairs through an added resistance.

17. A network in accordance with claim 12 and an added capacitor connected in shunt at one end of the network, the capacitance of said added capacitor being proportioned with respect to the leakage inductance of said inductors and the stray capacitances to provide a low-pass filter having a cut-off above the highest frequency to be transmitted by the network.

18. A network in accordance with claim 12 in which inductance is added in series with one of said inductors in each of said pairs, the value of said inductance being proportioned with respect to a negative reactive component associated with one of said load impedances to provide a low-pass filter having a cut-off above the highest frequency to be transmitted by the network.

SIDNEY DARLINGTON.

Certificate of Correction

Patent No. 2,301,023.

November 3, 1942.

SIDNEY DARLINGTON

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, lines 24, 25, and 26, and page 3, first column, lines 5, 6, and 7, for that portion of the equation reading

$$\left(\sqrt{\frac{R_2}{R_1}-1}\right)^2 \text{ read } \left(\sqrt{\frac{R_2}{R_1}}-1\right)^2$$

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 11th day of January, A. D. 1944.

[SEAL]

HENRY VAN ARSDALE,
Acting Commissioner of Patents.