Oct. 23, 1934. O. J. ZOBEL 1,977,751

WAVE TRANSMISSION NETWORK

Filed March 18, 1933

FIG. 1

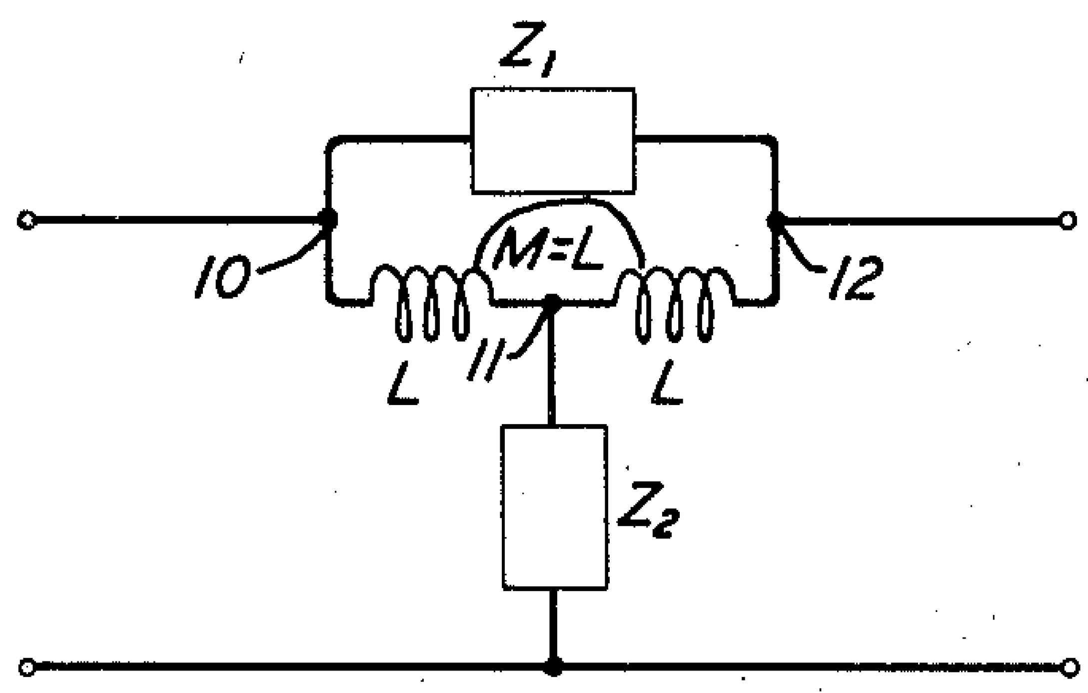



FIG. 2

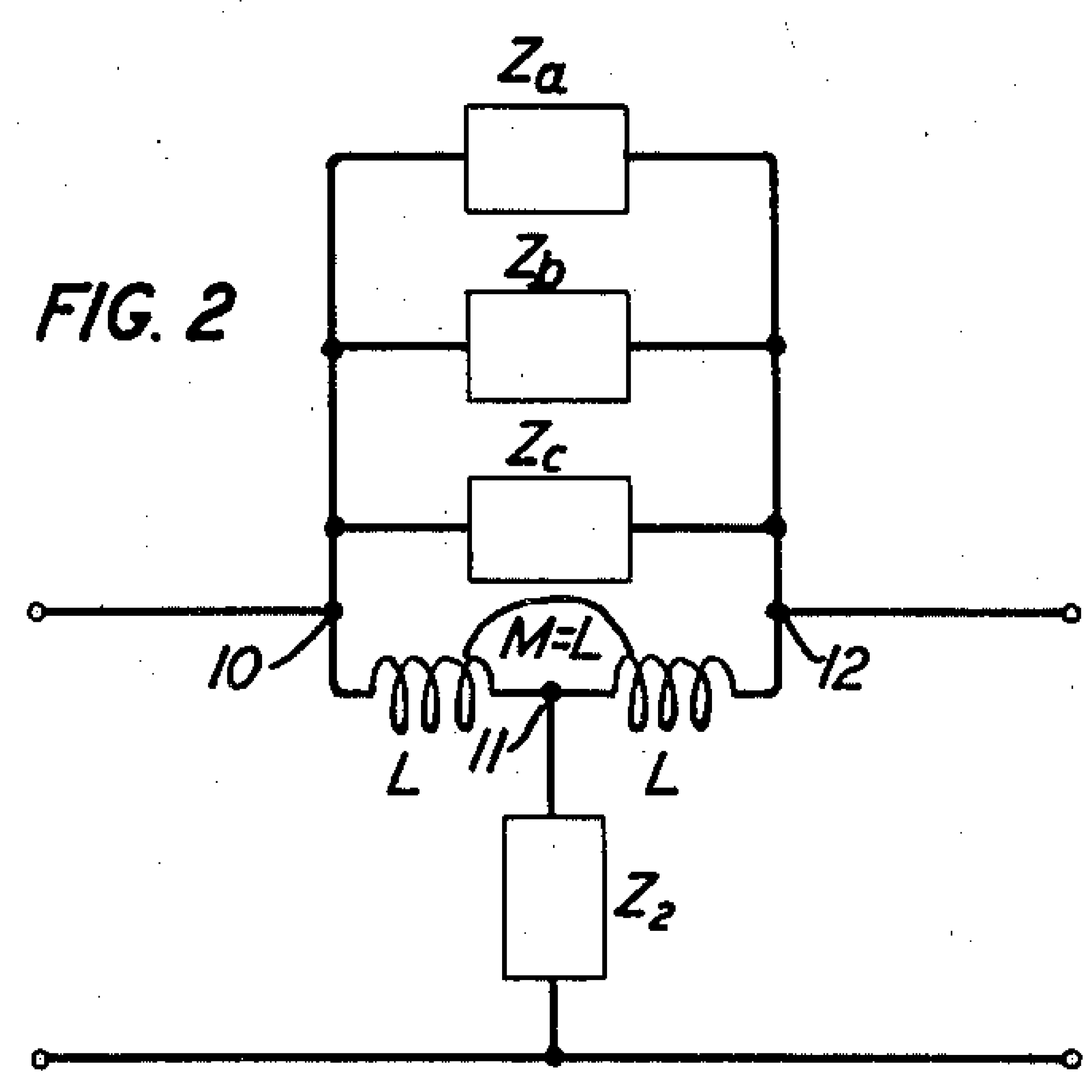



FIG. 3

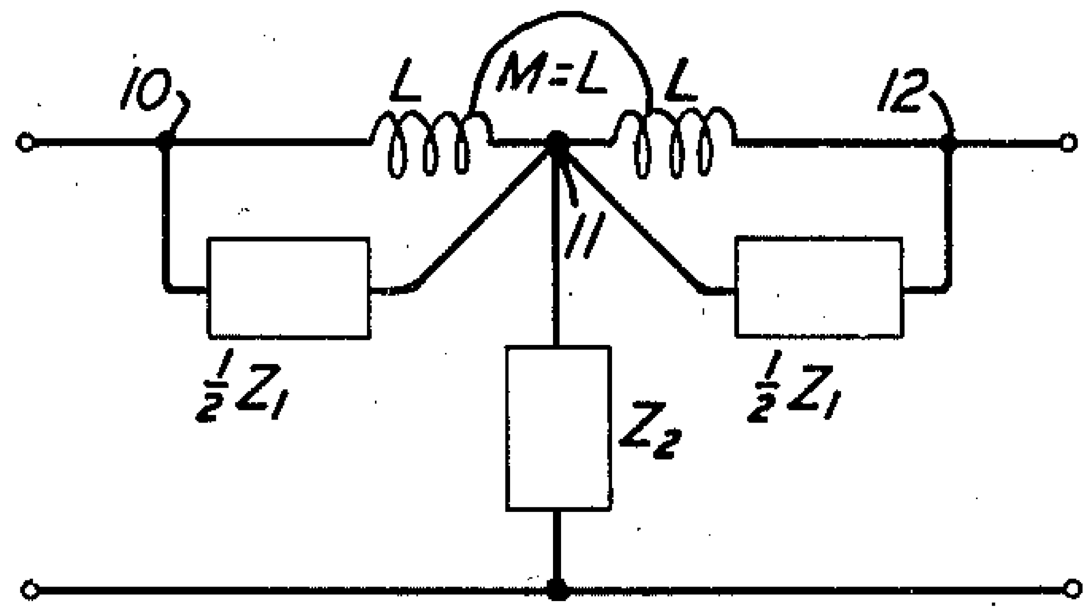



FIG. 4

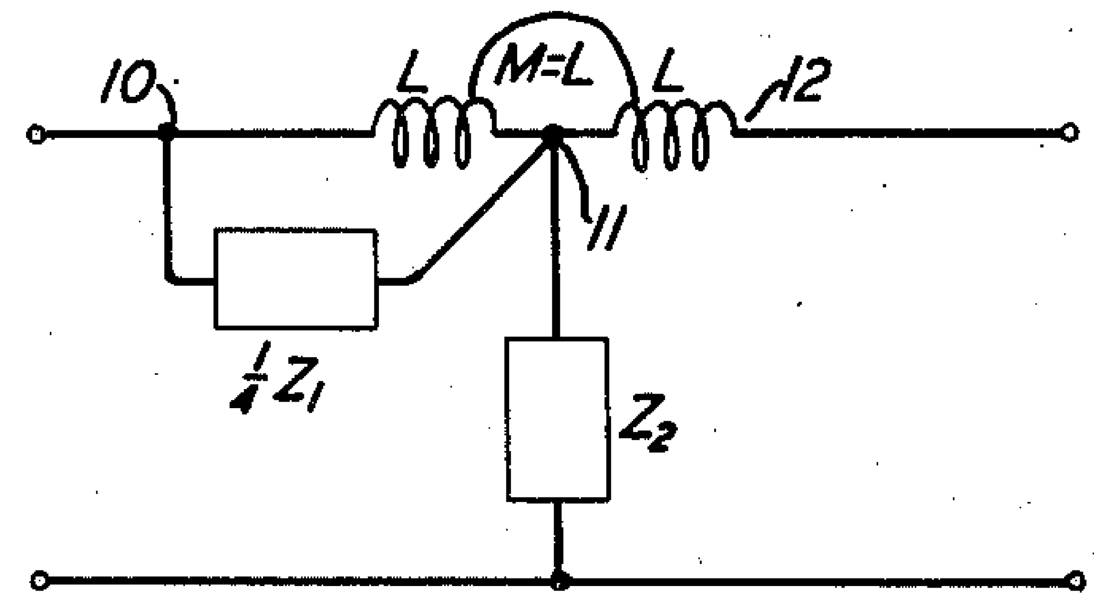



FIG. 5

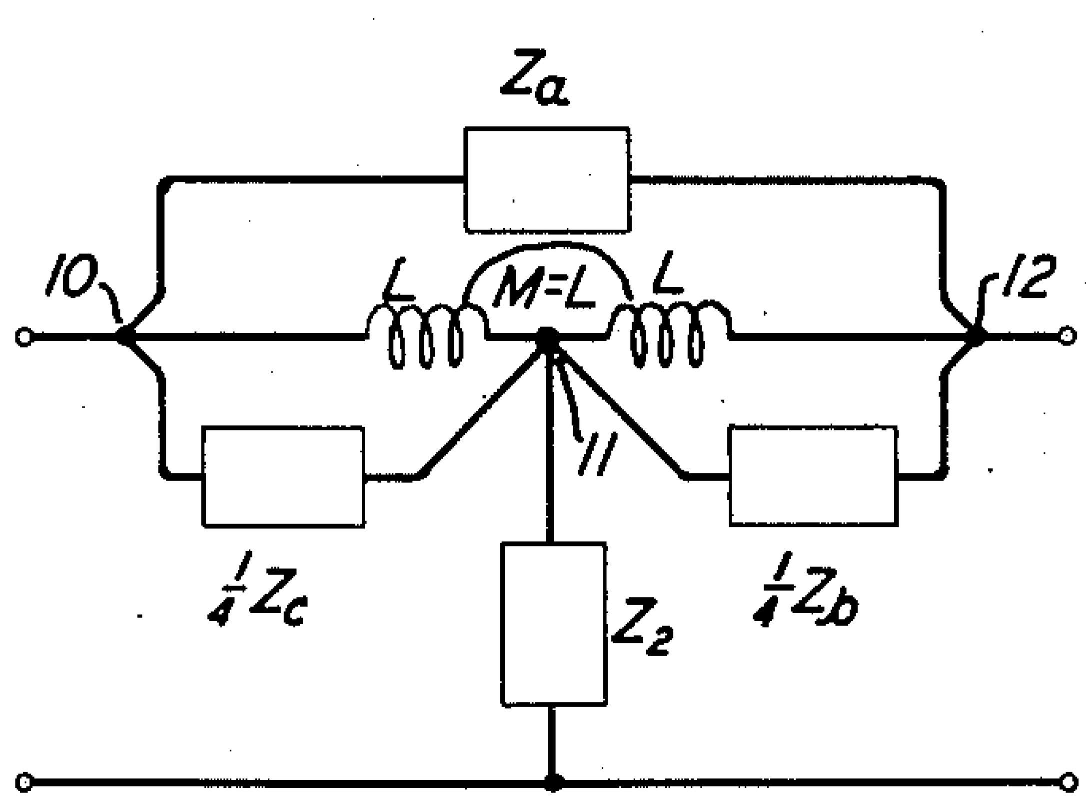
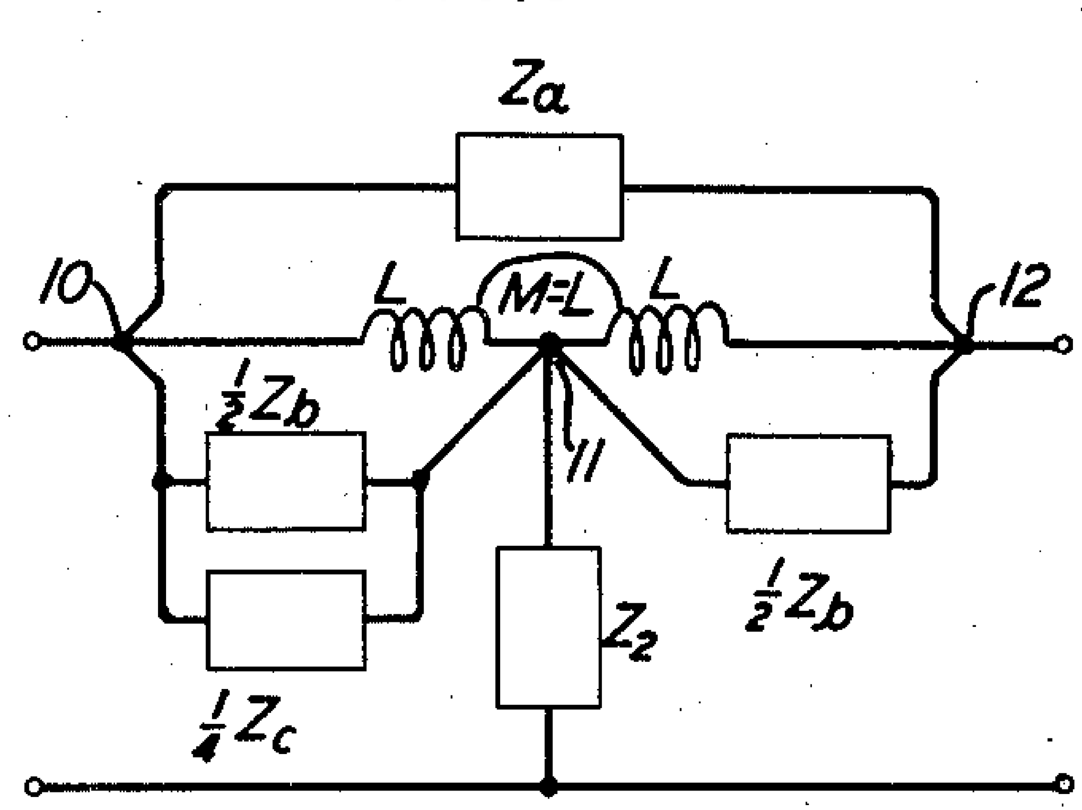



FIG. 6

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Patented Oct. 23, 1934 1,977,751

# UNITED STATES PATENT OFFICE

1,977,751

## WAVE TRANSMISSION NETWORK

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Application March 18, 1933, Serial No. 661,593

12 Claims. (Cl. 178—44)

This invention relates to wave transmission networks and more particularly to reactance networks, such as broad band wave filters, of the unbalanced type in which one side of the circuit may be grounded.

An object of the invention is to provide a new and improved type of wave transmission network which is equivalent in its transmission characteristics to known types of networks, but the component reactances of which fall within a different range of values.

Another object is to permit the construction of transmission networks of the bridged-T type which otherwise would require the use of reactance elements which are too large or too small to be built commercially.

A further object of the invention is to reduce the cost of manufacturing wave filters, especially those of the unbalanced type.

The bridged-T type of network is commonly employed in unbalanced circuits since, for such circuits, it provides a network having the same degree of generality in transmission characteristics as is given by the lattice network for balanced systems. In one form, the bridged-T network comprises a bridging branch and a central branch, connected by means of a unity ratio transformer the two windings of which are connected series aiding and have substantially perfect coupling. In certain instances, however, the component reactance elements required to build the bridging branch used in this type of network may involve inductance coils which are too large for economical manufacture, or condensers which are too small to permit the required precision of adjustment. In accordance with the present invention these difficulties are obviated by resorting to a new type of network section in which the impedance of the bridging branch may be reduced by a factor of two or a factor of four. This means that the inductances may be made one-half or one-fourth their former values, and the capacitances may be increased to twice or four times their former values. In this way, the component reactance elements of the bridging branch fall within an entirely different range of values than they otherwise would. The inductance coils may then be manufactured more economically and the condensers may be adjusted with the required precision. This desirable result is accomplished by shunting all or a part of the bridging impedance across one only of the windings of the coupling transformer. The transmission and impedance characteristics of the network are left undisturbed by this modification.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, of which

Figures 1 and 2 show schematically a transmission network of the bridged-T type, to which the invention is applicable; and

Figs. 3, 4, 5 and 6 illustrate various embodiments of the invention.

The transmission network shown schematically in Fig. 1 is of the well known bridged-T type. It comprises a transformer having two equal windings L, L connected series aiding with mutual inductance M equal substantially to L, a bridging impedance $Z_1$ connected between the outer terminals 10, 12 of the transformer, and a shunt impedance $Z_2$ connected from the common terminal 11 of the two inductances L, L to the other side of the line, which may be grounded or otherwise fixed in potential. The impedances $Z_1$ and $Z_2$ may comprise reactances only, or both resistance and reactance elements, and generally they will have different impedance characteristics. The network has the same degree of generality in respect to its transmission and impedance characteristics as can be obtained with any four-terminal transmission network made up wholly of passive impedance, and it may be made either balanced or unbalanced in form. For a more detailed description, explaining how the network may be designed to have any desired transmission characteristics, reference is made to the patent to H. W. Bode, No. 1,828,454, issued October 20, 1931.

In certain instances it has been found that the network shown in Fig. 1 may be built more economically if the impedance required for the branch $Z_1$ is reduced in magnitude. For example, the inductances may be so large that they cannot be conveniently wound on a single core, or the capacitances may be so small that it is impossible to obtain the necessary precision of adjustment. In accordance with the invention these restrictions are removed by resorting to a new type of network section in which a part or all of the impedance $Z_1$ is shunted across one only of the transformer windings L. In one embodiment of the invention, shown schematically in Fig. 3, the bridging impedance $Z_1$ is replaced by two impedances each equal to $\frac{1}{2}Z_1$, one being shunted across each of the windings L. The inductances forming the impedance $\frac{1}{2}Z_1$ will, of course, be only one-half the magnitude of those required for the impedance $Z_1$, and, likewise, the capacitances comprising the impedance $\frac{1}{2} Z_1$ will be of twice the magnitude of those used in the impedance $Z_1$. In another form of the invention, illustrated by the schematic circuit of Fig. 4, the bridging impedance $Z_1$ is replaced by a single impedance equal in magnitude to $\frac{1}{4} Z_1$, shunted across only one winding L, between the terminals 10, 11. In this latter case the inductances are reduced to one-fourth and the capacitances are increased by a factor of four, as compared with the corresponding elements required in the impedance $Z_1$. In this way the elements required for the bridging branch are made to fall within an entirely different range of values, permitting the convenient building of the inductance coils and allowing the requisite close adjustment of the condensers.

In a modification of the invention only a part of the bridging impedance is relocated. In Fig. 2 the impedance $Z_1$ has been replaced by the three branches $Z_a$, $Z_b$ and $Z_c$, the parallel impedance of which is equal to $Z_1$. In equation form,

$$\frac{1}{Z_1}=\frac{1}{Z_a}+\frac{1}{Z_b}+\frac{1}{Z_c} \qquad (1)$$

As shown in Fig. 5, the portion of the bridging impedance represented by the impedance $Z_b$ may be replaced by an impedance in magnitude equal to $\frac{1}{4} Z_b$ shunted across only one of the windings L, between the terminals 11, 12. Likewise, the part of $Z_1$ represented by $Z_c$ may be replaced by the impedance $\frac{1}{4} Z_c$ shunting one of the transformer windings L, between terminals 10, 11. The two impedances $\frac{1}{4} Z_b$ and $\frac{1}{4} Z_c$ may, if desired, be connected across the same winding L, for example, between the terminals 10, 11. In this way the portion of the bridging impedance $Z_1$ having elements which are satisfactory in size is left undisturbed, whereas the other parts of $Z_1$ are altered in magnitude by a factor of four and connected in parallel with only one of the transformer windings L. As shown in Fig. 6 the impedance $\frac{1}{4} Z_b$ of Fig. 5 may be replaced by two impedances each equal to $\frac{1}{2} Z_b$, one being shunted across each of the windings L. Other combinations and permutations involving the impedances $Z_a$, $Z_b$ and $Z_c$, which may be advantageously employed under certain circumstances, will readily suggest themselves. However, the networks illustrated by Figs. 5 and 6 are representative.

In the arrangements shown in Figs. 3, 5 and 6 if the impedances connected in parallel with the transformer windings comprise a shunting capacitance its value may be decreased to compensate individually for the inevitable interwinding capacitances of the two windings, L, L of the transformer, effective, respectively, between the terminals 10, 11 and between the terminals 11, 12. When this is done an improvement is effected in the transmission and impedance characteristics of the networks.

As mentioned above, the networks of the invention may be employed where any other four-terminal transducer, comprising only passive impedances, may be used. The invention is applicable, for example, to wave filters, phase correctors, delay networks and other transmission networks.

What is claimed is:

1. A wave transmission network comprising a pair of equal inductances, inductively coupled, in series with one side of the line, said inductances being connected in series aiding relation, two impedances, one shunted across each of said inductances, and a third impedance connected from the junction of said inductances to the other side of the line.

2. A wave transmission network comprising in one side of the line a pair of equal inductances connected series aiding with unity coupling factor, a pair of equal impedances, one of said impedances being connected in parallel with each of said inductances, and a third impedance connected between the common terminal of said pair of inductances and the other side of the line.

3. A wave transmission network having a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, in one of said paths a transformer having two equal windings connected series aiding with unity coupling factor, two general impedances, one of said impedances shunting each of said transformer windings, and a third general impedance connected between the junction point of said transformer windings and a point in the other of said paths.

4. A wave transmission network having a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a pair of equal inductances connected series aiding with unity coupling factor in one of said paths, a pair of equal impedances, one of said impedances shunting each of said inductances, and a third impedance included in a shunt path between the junction point of said inductances and a point in the other of said paths.

5. A wave transmission network comprising a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a pair of equal inductances connected series aiding with unity coupling factor in one of said paths, a pair of equal reactances, one of said reactances shunting each of said inductances, and a third reactance connected between the junction point of said inductances and a point in the other of said paths.

6. A wave transmission network comprising a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a pair of equal inductances connected series aiding with unity coupling factor in one of said paths, a general impedance connected in parallel with one of said inductances, and a second general impedance connected between the junction point of said inductances and a point in the other of said paths.

7. A wave transmission network comprising a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a pair of equal inductances connected series aiding with unity coupling factor in one of said paths, a general impedance connected in parallel with said inductances between the outer terminals thereof, a pair of equal impedances, one of said pair of impedances being connected in parallel with each of said inductances, and a fourth general impedance connected between the junction point of said inductances and a point in the other of said paths.

8. A wave transmission network comprising a pair of input terminals and a pair of output terminals, said network comprising an electrical path between each input terminal and a corresponding output terminal, a pair of equal inductances

connected series aiding with unity coupling factor in one of said paths, a general impedance connected in parallel with said inductances between the outer terminals thereof; a second general impedance shunting one of said inductances, a third general impedance shunting the other of said inductances, and a fourth general impedance connected between the junction point of said inductances and a point in the other of said paths.

9. A wave transmission network in the form of a T-network, the series arms of the T-network comprising a pair of equal inductances connected in series aiding relation with mutual inductance therebetween, a general impedance shunting one of said inductances, and a second general impedance shunting the other of said inductances, and the shunt arm of the T-network comprising a third general impedance.

10. A wave transmission network in the form of a T-network, the series arms of the T-network comprising a pair of equal inductances connected in series aiding relation with mutual inductance therebetween substantially equal in magnitude to the self-inductance of one of said equal inductances, and a general impedance shunted across one of said inductances, and the shunt arm of the T-network comprising a second general impedance having a characteristic differing from that of said first-mentioned general impedance.

11. A wave transmission network of the ladder type comprising a pair of equal impedances connected in series in one side of the line and a third impedance in shunt with the line, connected between the common terminal of said pair of equal series impedances and the other side of the line, said equal series impedances comprising two equal inductances connected in series aiding relation with unity coupling factor, and a pair of equal impedances, one shunting each of said inductances.

12. An electric wave filter comprising a pair of equal inductances connected series aiding with unity coupling factor, a reactive impedance shunting one of said inductances, a second reactive impedance shunting the other of said inductances, and a third reactive impedance having one of its terminals connected to the junction point of said pair of equal inductances.

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