

Feb. 4, 1936.

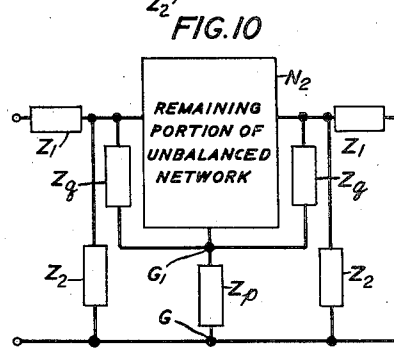
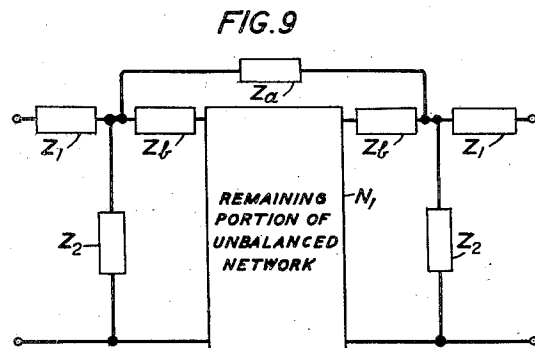
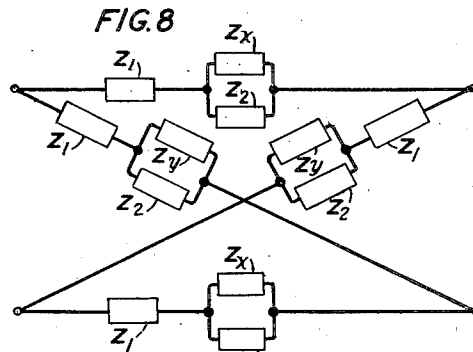
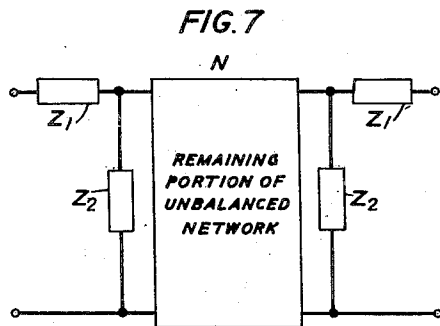
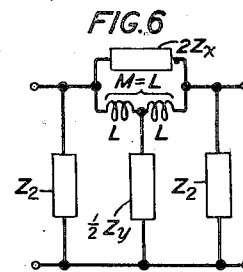
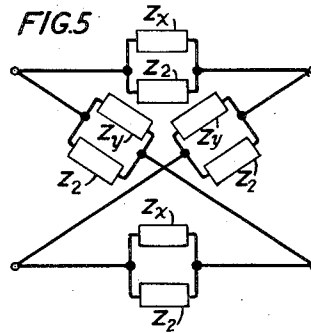
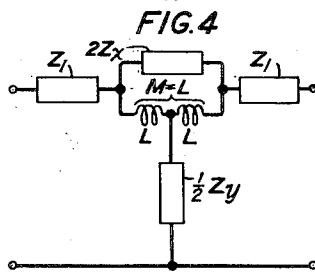
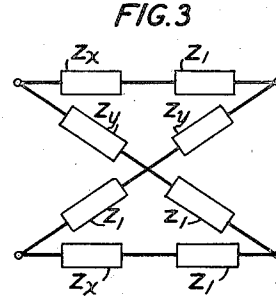
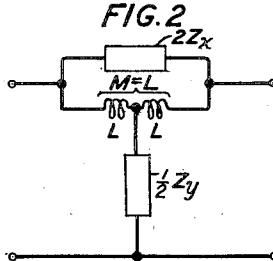
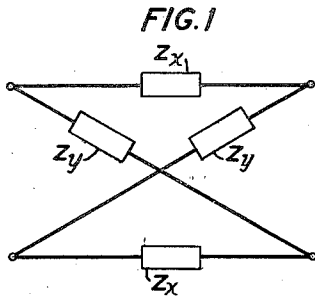
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2,029,698

WAVE TRANSMISSION NETWORK

Filed April 28, 1933

3 Sheets-Sheet 1



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WAVE TRANSMISSION NETWORK

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3 Sheets-Sheet 2

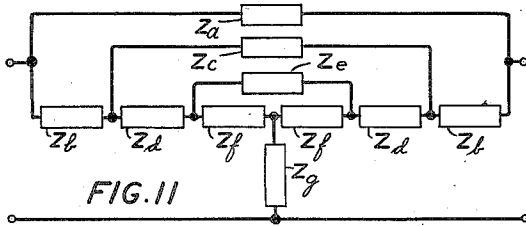


FIG. 11

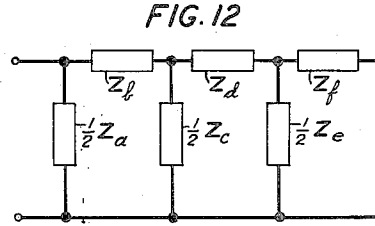


FIG. 12

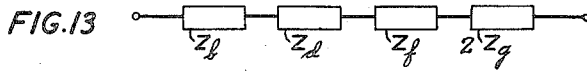


FIG. 13

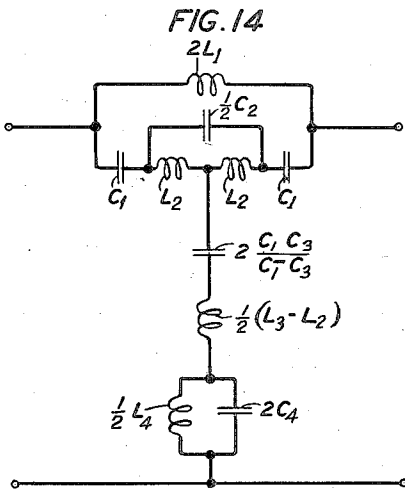


FIG. 14

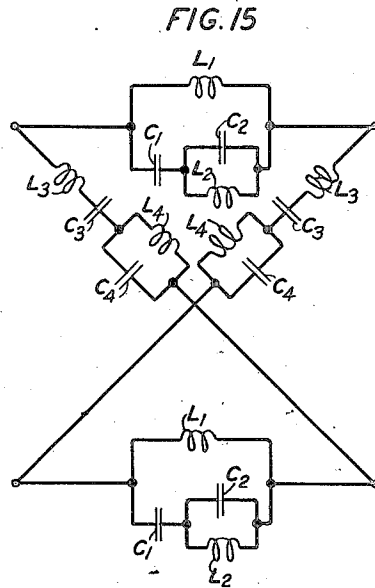


FIG. 15

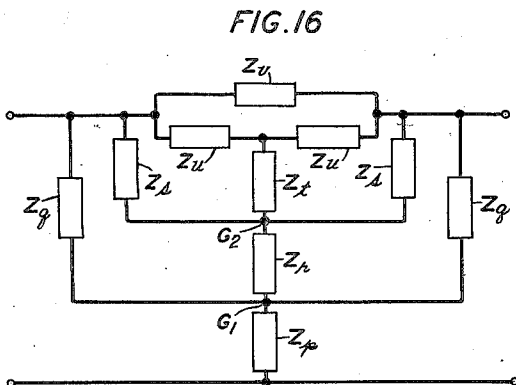


FIG. 16

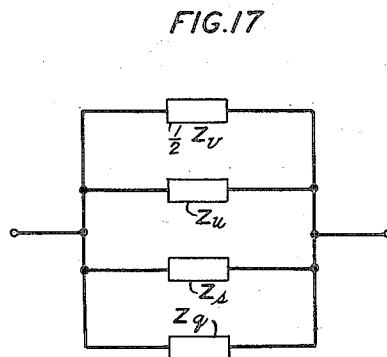


FIG. 17

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WAVE TRANSMISSION NETWORK

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FIG. 18

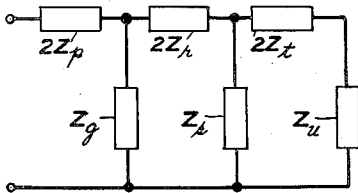


FIG. 19

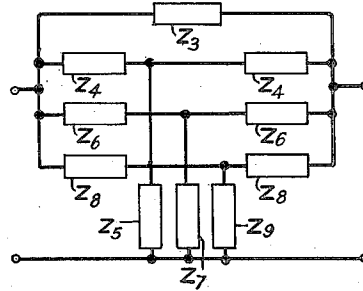


FIG. 20

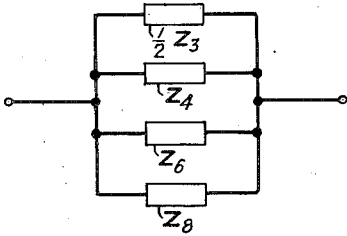


FIG. 21

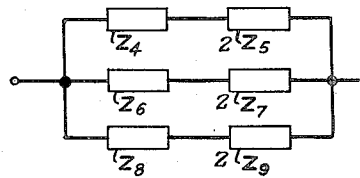


FIG. 22

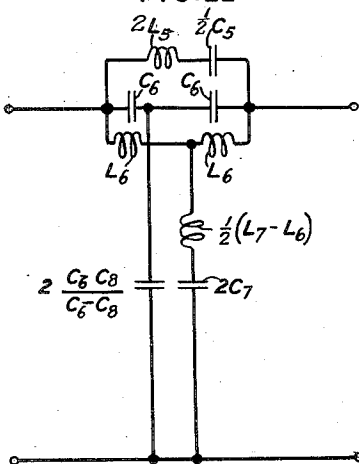
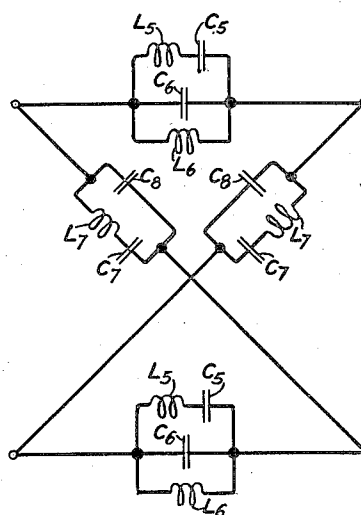


FIG. 23



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2,029,698

WAVE TRANSMISSION NETWORK

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York, N. Y., a corporation of New York

Application April 28, 1933, Serial No. 668,312

13 Claims. (Cl. 178—44)

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

An object of the invention is the reduction of the number of elements required in a symmetrical network.

Another object is the elimination of the requirement of mutual inductance in building unbalanced networks.

A further object is to improve the transmission and impedance characteristics obtainable in unbalanced networks.

A feature of the invention is an unbalanced network in combination with ladder structures in the line on both sides of the network.

Another feature is a bridged-T network in which the series arms of the T-network comprise a succession of series impedances with new bridging arms connected across the junctions thus obtained.

Another feature is a bridged-T network in which the shunt arm comprises a succession of impedances connected in cascade, with separate shunting impedances connected from each side of the structure to the junction points thus formed in the shunt arm.

Another feature is a bridged-T network comprising a plurality of pairs of series arms and a plurality of shunt arms.

As a matter of convenience, transmission networks are often designed in the form of symmetrical lattice structures because the lattice equations are particularly simple and because this configuration gives the widest possible range of transmission and impedance characteristics obtainable from symmetrical networks. In many instances, however, the lattice is an unsatisfactory form in which to build the network since it frequently requires a large number of elements and, moreover, cannot be used in unbalanced systems.

A well known unbalanced equivalent of the symmetrical lattice is the bridged-T network, comprising a bridging impedance and a shunt impedance coupled by a unity ratio transformer. However, for complete equivalence it is necessary that this coupling transformer be a perfect one, that is, one having infinitely great winding inductances and unity coupling. In accordance with the present invention certain modified and improved forms of the bridged-T network are presented in which the coupling transformer has been eliminated entirely and no mutual inductance is required in their construction.

The networks may be made the equivalent of the lattice in their transmission properties but are unbalanced in form, with a consequent saving in the number of elements required. These modifications consist in the use of a ladder structure in the line on both sides of the bridged-T network; the representation of the series arms of the bridged-T as a succession of series impedances with new bridging arms across the junctions thus obtained; the representation of the shunt arm of the bridged-T as a succession of impedances in tandem with new shunt impedances connected from each side of the structure to the new junction points; the use of extra series and shunt arms; or a combination of these various expedients.

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

Figs. 1, 3, 5, 8, 15 and 23 are schematic diagrams of symmetrical lattice networks;

Fig. 2 shows a conventional unbalanced bridged-T network which is the equivalent of the lattice of Fig. 1;

Fig. 4 illustrates a bridged-T network having external impedances in series with the line which may be made the equivalent of the lattice of Fig. 3;

Fig. 6 represents a bridged-T network having external impedances in shunt with the line which may be made the equivalent of the lattice of Fig. 5;

Fig. 7 illustrates an embodiment of the invention in which a ladder structure is placed in the line on each side of the remaining portion of the unbalanced network, the entire structure being the equivalent of the lattice of Fig. 8;

Figs. 9 and 10 are diagrammatic circuits showing how the invention may be applied in developing unbalanced structures;

Fig. 11 illustrates an embodiment of the invention in which the series arms of the bridged-T network consist of a succession of series impedances with new bridging branches connected between the junctions thus obtained, the entire structure being the equivalent of a lattice having the branch impedances shown in Figs. 12 and 13;

Fig. 14 illustrates a specific application of the invention represented schematically in Fig. 11, the network of Fig. 14 being equivalent to the lattice of Fig. 15,

Fig. 16 represents diagrammatically the ap-

plication of the invention to a bridged-T network in which the shunt arm comprises a succession of impedances connected in series, with separate shunting impedances connected from each side of the structure to the junction points thus formed, the entire network being equivalent to a lattice made up of the branch impedances shown in Figs. 17 and 18.

Fig. 19 shows diagrammatically the embodiment of the invention in a bridged-T network comprising a plurality of pairs of series arms and a plurality of shunt arms, the structure being the equivalent of a lattice network having the branch impedances shown in Figs. 20 and 21; and Fig. 22 is a wave filter which utilizes the invention represented by the circuit of Fig. 19, the filter being equivalent to the lattice network of Fig. 23.

Fig. 1 shows schematically the well known symmetrical lattice type of network comprising two equal line impedances Z_x and two equal impedances Z_y connected diagonally between the input and output terminals. The impedances Z_x and Z_y are primarily reactances and may have any degree of complexity and any of a wide variety of schematic forms. Perhaps the simplest and best known unbalanced equivalent of the symmetrical lattice of Fig. 1 is the bridged-T network shown schematically in Fig. 2, in which the bridging branch has the impedance $2Z_x$ and the shunt branch has the impedance $\frac{1}{2}Z_y$. The two branches are coupled by means of a unity ratio transformer having two equal windings L , L connected series aiding between their outer terminals. If the transformer is so constructed that the windings, besides being equal, have very large inductances and substantially perfect coupling, that is to say, if the mutual inductance M therebetween is equal to L , then the network of Fig. 2 will be substantially equivalent to that of Fig. 1 with respect to its impedance and transmission characteristics. In order to attain complete equivalence, however, it is necessary that the coupling transformer should be a perfect one, that is, one having infinitely great winding inductances and unity coupling. For a more detailed description, explaining how the lattice network may be designed to have any desired transmission characteristics, reference is made to my prior Patent 1,828,454, issued October 29, 1931. In accordance with the present invention the use of a coupling transformer or mutual inductance is dispensed with entirely, in certain instances and the equivalence between the lattice network and the resultant unbalanced structure is thereby made more exact.

One method of eliminating the use of mutual inductance in an unbalanced network which may be made the equivalent of a lattice network depends upon the use of series impedances or shunt impedances, or a combination of both, to form a ladder network, in association with a bridged-T or other unbalanced structure. For example, if each branch of the lattice network contains a series impedance Z_1 , as shown in Fig. 3, then the impedance common to both branches may be placed in series with the line, as represented by the pair of impedances Z_1 , Z_1 of Fig. 4. The remaining portion of the unbalanced network may then be built as a conventional bridged-T as shown in Fig. 4, or it may take the form of a modified bridged-T in which no transformer is required, as explained more fully hereinafter. On the other hand, if the two branches of the lattice

contain equal parallel impedances, as shown by Z_2 of Fig. 5, then these impedances may appear as a pair of impedances Z_2 , Z_2 shunting the line on either side of the bridged-T network, or other unbalanced structure, as shown in Fig. 6. In some instances it is possible to pick out a number of series and parallel impedances in succession, thus allowing a considerable portion of the original lattice to be represented as a ladder structure. This procedure is illustrated in Fig. 7, which shows an unbalanced network comprising a ladder structure in the line on both sides which may be made the equivalent of the lattice of Fig. 8. The remaining portion of the unbalanced network, indicated diagrammatically as N in Fig. 7, may then be built as a conventional bridged-T or as a modified bridged-T network as fully explained below. In order to make the unbalanced network of Fig. 7 equivalent to the lattice shown in Fig. 8, the remaining portion N must be made equivalent to a lattice having branch impedances Z_x and Z_y . As stated above, the ladder structure is not restricted to the two impedance branches Z_1 and Z_2 shown in Fig. 7, but may be extended to contain any number of series and shunt branches.

After the ladder development, as shown in Fig. 7, has been carried as far as possible, that is, until both branches of the reduced lattice no longer contain common series or shunt impedances, then, in accordance with the invention, the development may be carried out further by the introduction of a bridging impedance across the central portion of the network, or by the introduction of an impedance in series with the ground terminal of the central portion. If, for example, when the unbalanced structure has been developed to the point illustrated in Fig. 7, it is found that the line branch Z_x of Fig. 8 resembles an inductance at zero frequency and a capacitance at infinite frequency, while the diagonal branch Z_y resembles a capacitance at zero frequency and an inductance at infinite frequency, then the central portion of the network may always be bridged by an inductance, represented by Z_a of Fig. 9. If the magnitude of the impedance Z_a is properly chosen, the reduced Z_x branch will now also resemble a capacitance at zero frequency and the ladder development may therefore be continued by the addition of a pair of equal capacitances in series with the line, as shown by Z_b , Z_b in Fig. 9. Or, if preferred, a similar result may be obtained by using a capacitance or a capacitance and an inductance in parallel for the bridging impedance Z_a , in which case the series impedance Z_b would be an inductance or an inductance and a capacitance in series. The remaining portion of the unbalanced network, indicated by N_1 in Fig. 9, must then be made equivalent to a lattice having line branches equal to the impedance Z_x reduced by the removal of a shunt impedance equal to $\frac{1}{2}Z_a$ and then the series impedance Z_b , and diagonal branches equal to the impedance Z_y minus the impedance Z_b .

Conversely, the ladder development may be continued, after reaching the stage illustrated in Fig. 7, by introducing an impedance Z_p in series with the ground terminal G of the network as a whole and what may be termed a false ground G_1 , as shown in Fig. 10. If the impedance Z_p is a properly chosen capacitance then the reduced diagonal branch Z_y will resemble an inductance at zero frequency and the ladder development may therefore be continued by taking a shunt inductance out of each branch of the lattice and

by introducing a pair of equal inductances, one being connected between each side of the remaining structure N_2 and the false ground G_1 as represented by the impedances Z_q , Z_q of Fig. 10. The remaining portion N_2 of the unbalanced structure must be made equivalent to a lattice network having line branches equal to Z_x reduced by the removal of the shunting impedance Z_q , and diagonal branches equal to Z_y after a series impedance equal to $2Z_p$ and then the shunt impedance Z_q have been taken away, as already explained. Alternatively, an inductance or an inductance and a capacitance in series may be used for the impedance Z_p , in which case the shunt impedance Z_q would be a capacitance or a capacitance and an inductance in parallel.

The procedure described above in connection with Fig. 9 may, in certain cases, be repeated a number of times, producing a modified bridged-T network in which the series arms are represented by a succession of pairs of series impedances, such, for example, as Z_b , Z_d and Z_f of Fig. 11, with new bridging arms across the junctions thus obtained, as indicated by the impedances Z_a , Z_c , and Z_e in the same figure. The shunt branch of the bridged-T network is represented by the impedance Z_g . The unbalanced network of Fig. 11 is the equivalent of a symmetrical lattice having the line impedances and the diagonal impedances shown, respectively, in Figs. 12 and 13. It will be noted that no mutual inductance is required for the construction of the network of Fig. 11.

A specific application of the network of Fig. 11 is shown in the wave filter of Fig. 14, which is the unbalanced equivalent of the symmetrical lattice shown in Fig. 15, and employs no mutual inductance. Each line branch of the lattice network of Fig. 15 consists of an inductance L_1 shunted by an arm comprising a capacitance C_1 in series with an anti-resonant loop made up of an inductance L_2 and a capacitance C_2 . Each diagonal branch of the lattice comprises an inductance L_3 and a capacitance C_3 in series, the combination being connected in series with a loop consisting of an inductance L_4 and a capacitance C_4 in parallel. The series arms of the modified bridged-T network shown in Fig. 14 consist of a pair of equal inductances L_2 and a pair of equal capacitances C_1 ; the two bridging arms are constituted, respectively, by an inductance of value $2L_1$ and a capacitance of value $\frac{1}{2} C_2$; and the shunt branch comprises a loop made up of an inductance of value $\frac{1}{2} L_4$ in parallel with a capacitance of value $2C_4$, the loop being connected in series with an inductance of value $\frac{1}{2} (L_3 - L_2)$ and a capacitance of value

$$2 \frac{C_1 C_3}{C_1 - C_3}$$

The relationship existing between the elements comprising the bridged-T network of Fig. 14 and those forming the lattice shown in Fig. 15 is clearly brought out by the notation used in the two figures. The only restriction imposed upon the values of the elements is that L_3 shall be equal to or larger in magnitude than L_2 , and C_1 shall be equal to or larger than C_3 , in order that all of the elements of the modified bridged-T network will be physically realizable, without resort to the use of mutual inductance. The filter used in the illustration is an all-pass structure having an image impedance of 1000 ohms. The values of the elements are as follows:

$$\begin{aligned} L_1 &= 1.50 \text{ henries} & C_1 &= 2.00 \text{ microfarads} \\ L_2 &= 0.33 \text{ henry} & C_2 &= 1.00 \text{ microfarad} \end{aligned}$$

$$\begin{aligned} L_3 &= 0.67 \text{ henry} & C_3 &= 1.50 \text{ microfarads} \\ L_4 &= 1.33 \text{ henries} & C_4 &= 0.75 \text{ microfarad} \end{aligned}$$

It is to be noted that the network of Fig. 14 may be built without using mutual inductance, but if a simple bridged-T structure were employed mutual inductance would be required.

It is sometimes found that the process described above in connection with Fig. 10 may also be repeated several times, resulting in the modified bridged-T network illustrated diagrammatically in Fig. 16, in which the shunt arm is constituted by a number of series impedances, such as Z_p , Z_r and Z_t , with the separate shunt impedances Z_q and Z_s connected from each side of the structure to the junction points or false grounds G_1 and G_2 , as shown in the figure. The remainder of the network is an ordinary bridged-T having the pair of impedances Z_u for the series arms and the impedance Z_v for the bridging arm. The unbalanced structure of Fig. 16 is the equivalent of a symmetrical lattice network having the line impedances and the diagonal impedances shown, respectively, in Figs. 17 and 18. Here, again, it will be seen that no transformers nor mutual inductance is required in the construction of this type of unbalanced network, as shown in Fig. 16.

Another method of eliminating the use of mutual inductance in the equivalent unbalanced network involves increasing the number of series branches and also the number of shunt branches employed in the bridged-T, giving a configuration of the type shown diagrammatically in Fig. 19, in which the series arms are the three pairs of impedances Z_4 , Z_6 and Z_8 , and the shunt branches associated, respectively, with the above enumerated series arms are the impedances Z_5 , Z_7 and Z_9 , the bridging branch being constituted by the impedance Z_3 . The unbalanced network of Fig. 19 is the equivalent of a symmetrical lattice having the line impedances and the diagonal impedances shown, respectively, in Figs. 20 and 21. It will be observed that the conversion from the lattice to the form of bridged-T network represented by Fig. 19 will be possible provided the branches of the lattice can be arranged as combinations of parallel impedances such that each parallel arm of one can be subtracted from one of the arms of the other without leaving a negative remainder. For example, one of the parallel arms of the branch impedance shown in Fig. 20 consists of the impedance Z_6 , and, therefore, the other branch impedance, shown in Fig. 21, is required to have an arm comprising an impedance Z_8 in series with a positive, that is, a physical, impedance $2Z_6$, which latter impedance may, of course be zero.

The equivalence of the bridged-type network of Fig. 19 to a symmetrical lattice having the line and diagonal impedance branches shown in Figs. 20 and 21 rests upon the conversion of simple lattice structures to T-networks. The lattice having the branches shown in Figs. 20 and 21 may be considered to be a combination of four simple lattices connected in parallel at both ends, terminal for terminal. In one of these simple lattices each line impedance is Z_4 and each diagonal branch consists of Z_4 in series with $2Z_5$. The second lattice has a line impedance Z_6 and a diagonal impedance comprising Z_6 in series with $2Z_7$. The third lattice has Z_8 for the line branch and Z_8 in series with $2Z_9$ for the diagonal branch, and the fourth lattice has a line impedance $\frac{1}{2} Z_3$ with an infinite impedance for its diagonal branches.

Each of these simple lattices may be converted to an equivalent T-network in a manner well-known in the art. A lattice having a pair of impedances A, A as line branches and impedances B, B as diagonal branches is the equivalent of a T-network having two series arms A, A and an intervening shunt arm equal to $\frac{1}{2}(B-A)$. In this connection reference is made to equation (24) of the paper by O. J. Zobel entitled, "Theory and Design of Uniform and Composite Electric Wave Filters" published in Bell System Technical Journal for January 1923. The same equivalence is shown in Figs. 24A and 24B appearing in Appendix D, page 281, of K. S. Johnson's "Transmission Circuits for Telephonic Communication" published by D. Van Nostrand Company.

Applying the process outlined to the networks under consideration, the simple lattice having Z_8 for the line branch and Z_8 in series with $2Z_9$ for the diagonal branch may be converted into the simple T-network in Fig. 19 having Z_8 for the series arms and $\frac{1}{2}(Z_8+2Z_9-Z_8)=Z_9$ for the shunt arm. The other simple T-networks of Fig. 19 are found in the same way. The bridging branch Z_3 may be considered to be a T-network having two series arms each equal to $\frac{1}{2}Z_3$ with an interposed shunt branch infinite in impedance.

A specific application of the network of Fig. 19 is illustrated in the low pass wave filter of Fig. 22, which is the unbalanced equivalent of the symmetrical lattice shown in Fig. 23, and requires no mutual inductance in its construction. Each line branch of the lattice network of Fig. 23 consists of three parallel arms, in one of which are the inductance L_5 and the capacitance C_5 in series, in another is the capacitance C_6 , and in the third, the inductance L_6 . Each diagonal branch of the lattice is comprised of two arms, one made up of the inductance L_7 and the capacitance C_7 in series, and the other consisting of the capacitance C_8 . In the modified bridge-T network of Fig. 22 the bridging arm is constituted by the inductance $2L_5$ and the capacitance $\frac{1}{2}C_5$ in series; one pair of series arms are formed of the capacitances C_6 , the shunt branch associated therewith being a capacitance equal to

$$2\frac{C_6C_8}{C_6-C_8};$$

and the other pair of series arms consist of the inductances L_6 , the associated shunt branch being made up of an inductance equal to $\frac{1}{2}(L_7-L_6)$ in series with a capacitance equal to $2C_7$. The designations employed in Figs. 22 and 23 clearly indicate the relationship between the component elements comprising the two networks. The only restrictions imposed upon the values of the elements are that the inductance L_7 must be equal to or larger in magnitude than is L_6 , and the capacitance C_6 must be equal to or larger than C_8 , so that all of the elements of the modified bridged-T network will be physically realizable without using mutual inductance. As an illustrative example, a low pass filter has been designed which employs elements having the following values:

$L_5=0.67$ henry	$C_5=0.60$ microfarad
$L_6=0.50$ henry	$C_6=1.00$ microfarad
$L_7=1.33$ henries	$C_7=0.75$ microfarad
	$C_8=0.50$ microfarad

Here, again, it should be noted that the network of Fig. 22 could not be constructed as a simple bridged-T network without resort to the employment of mutual inductance.

The equivalence of the bridged-type network shown in Fig. 22 to the lattice of Fig. 23 becomes readily apparent when the relationship of the component impedances to those of Fig. 19 is pointed out. The impedance Z_3 of Figs. 19, 20 and 21 corresponds to the inductance $2L_5$ connected in series with the capacitance $\frac{1}{2}C_5$ in Figs. 22 and 23, Z_4 corresponds to C_6 , Z_5 to the capacitance of value

$$2\frac{C_6C_8}{C_6-C_8},$$

Z_6 to L_6 , and Z_7 corresponds to $2C_7$ in series with an inductance equal to $\frac{1}{2}(L_7-L_6)$. In Figs. 22 and 23 there are no impedances corresponding to Z_8 and Z_9 . Thus the T-network in Fig. 22 having the series arms C_6 , C_6 and the shunt arm

$$2\frac{C_6C_8}{C_6-C_8}$$

is seen to be the unbalanced equivalent of the simple lattice in Fig. 23 having C_6 for each line branch and C_8 for each diagonal branch. Likewise, the T-network in Fig. 22 having L_6 , L_6 as series arms and having a shunt arm consisting of $2C_7$ in series with $\frac{1}{2}(L_7-L_6)$ is the equivalent of the simple lattice in Fig. 23 comprising L_6 as the line impedances and L_7 in series with C_7 as the diagonal branches.

The examples described are, of course, only illustrations of particular applications of the invention. It will be understood, also, that the various methods presented for the construction of an unbalanced network which does not require the use of mutual inductance but which may be made the equivalent of a symmetrical lattice network are not inconsistent and may be used, if desired, in combination to produce an extremely elaborate network.

What is claimed is:

1. A wave transmission network comprising two equal ladder-type sections and a bridged-type central portion connected in series therebetween, the impedance branches of said central portion being primarily reactances, said ladder sections being symmetrically located with respect to said central portion, and said ladder sections and said central portion cooperating to provide a network having the same transmission characteristics as a given lattice-type network.

2. An unbalanced wave transmission network comprising two equal unbalanced ladder-type sections and an unbalanced bridged-type central portion connected in series therebetween, the lumped impedances forming said central portion being primarily reactance elements, said ladder sections being symmetrically placed with respect to said central portion, and said ladder sections being so proportioned with respect to said central portion that the entire structure constitutes a network having the same transmission characteristics as a given lattice-type network.

3. An unbalanced wave transmission network comprising two equal unbalanced ladder-type sections, an unbalanced bridged-type central portion connected in series therebetween, a pair of equal impedances connected in series with said central portion, one on either side thereof, and an impedance connected between the outer terminals of said pair of equal impedances, said ladder sections being symmetrically placed with respect to said central portions, the impedance elements forming said central portion being primarily reactances and said network as a whole

having the same transmission characteristics as a given lattice-type structure.

4. An unbalanced wave transmission network having one side which may be grounded, said network comprising two equal ladder-type sections and an unbalanced central portion connected in series therebetween, said ladder sections being symmetrically placed with respect to said central portion, and said central portion comprising a shunt impedance connected between the grounded side of said network and a point in said central portion which may be termed a false ground, and a pair of equal impedances, one of said equal impedances being connected between said false ground and a point in the non-grounded side of said network, and the other of said equal impedances being connected between said false ground and a second point in the non-grounded side of said network, said second point being symmetrically located with respect to said first mentioned point.

5. A wave transmission network comprising two equal ladder-type end portions and a bridged-type central portion connected in series therebetween, the impedance branches of said central portion being primarily reactances, said end portions being symmetrically located with respect to said central portion, and said network being the electrical equivalent of a lattice-type network.

6. A wave filter comprising two equal ladder-type end portions and a bridged-type central portion connected in series therebetween, said end portions being symmetrically located with respect to said central portion, the impedance elements forming said central portion being primarily reactances, and said filter being the electrical equivalent of a lattice-type network comprising an impedance in a line branch and an impedance in a diagonal branch which are equal to each other.

7. An unbalanced wave filter comprising two similar unbalanced ladder-type end portions and an unbalanced bridged-type central portion connected therebetween, said end portions being symmetrically placed with respect to said central portion, the impedance elements forming said central portion being primarily reactances, and said filter being electrically equivalent to a lattice-type network having an impedance in a line branch which is equal to another impedance in a diagonal branch.

8. An unbalanced wave transmission network comprising two equal ladder-type end portions and an unbalanced bridged-type central portion connected therebetween, the lumped impedances forming said central portion being primarily reactance elements, said end portions being symmetrically located with respect to said central portion, and said network being electrically equivalent to a lattice-type network comprising an im-

pedance in a line branch and an impedance in a diagonal branch which are equal to each other.

9. A wave transmission network comprising two similar end portions of the ladder type, a central portion of the bridged type connected therebetween, said end portions being symmetrically located with respect to said central portion, a pair of equal impedances connected in series with said central portion, one on either side thereof, and a bridging branch connected between the outer terminals of said pair of equal impedances.

10. A wave transmission network comprising two similar ladder-type end portions and a bridged-type central portion connected therebetween, said end portions being symmetrically located with respect to said central portion, and said central portion comprising a plurality of pairs of series impedances and a plurality of bridging branches.

11. A wave transmission network comprising two similar ladder-type end portions and a bridged-type central portion connected therebetween, said end portions being symmetrically located with respect to said central portion, and said central portion comprising two equal series arms, a bridging branch, a shunt branch comprising a plurality of impedances connected in series, and a pair of equal impedances, one of said equal impedances being connected between one terminal of said bridging branch and a junction point formed by two of said impedances in said shunt branch, and the other of said impedances being connected between the other terminal of said bridging branch and the aforementioned junction point.

12. A wave transmission network comprising two similar ladder-type end portions and a bridged-type central portion connected therebetween, said end portions being symmetrically located with respect to said central portion, and said central portion comprising a bridging branch, a plurality of pairs of series arms, and a plurality of shunt branches, the number of shunt branches being equal to the number of pairs of series arms, and each of said shunt branches being associated with one pair of said series arms, one terminal of each of said shunt branches being connected, respectively, to the junction point formed by a pair of said series arms.

13. A wave transmission network comprising two equal ladder-type end portions and a bridged-type central portion connected therebetween, said end portions being symmetrically located with respect to said central portion, and said central portion comprising a bridging branch and a plurality of symmetrical T-networks connected in parallel.

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