

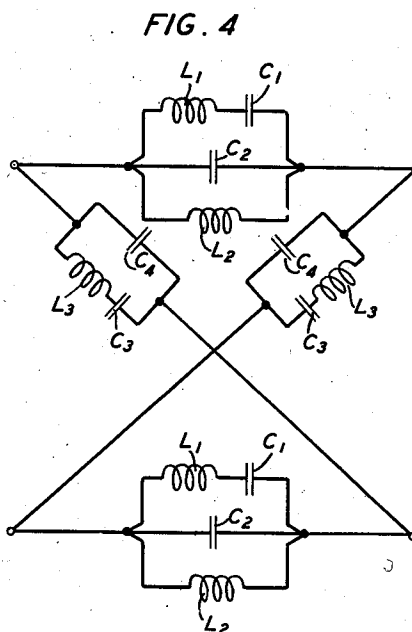
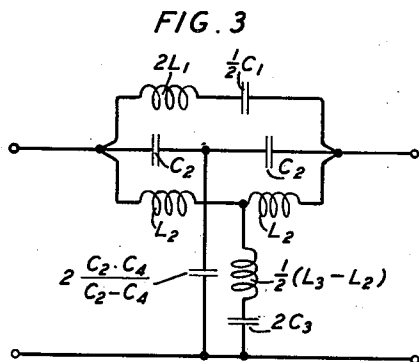
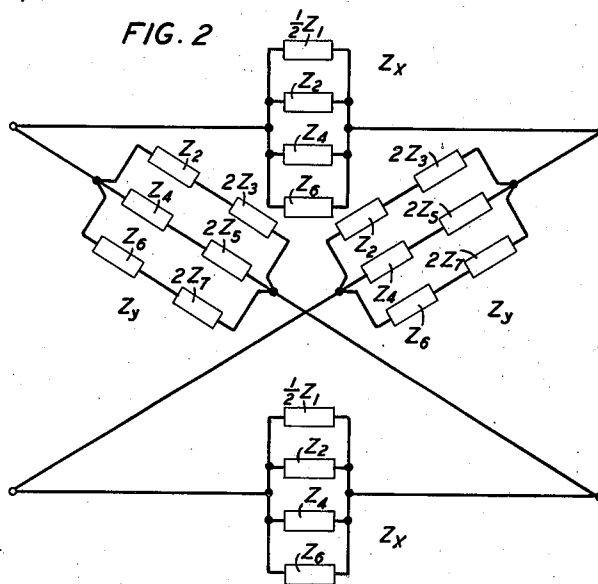
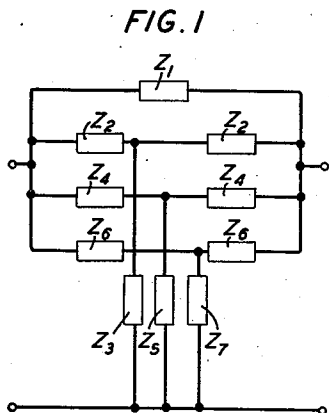
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WAVE TRANSMISSION NETWORKS

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WAVE TRANSMISSION NETWORKS

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668,312. Divided and this application Novem-
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This invention relates to wave transmission networks and more particularly to reactive networks, such as wave filters, of the unbalanced type in which one side of the circuit may be grounded. This application is a division of my copending application, Serial No. 668,312, filed April 28, 1933 which has matured into Patent 2,029,698, Feb. 4, 1936.

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 a bridged-type network comprising a plurality of pairs of series arms and a plurality of shunt branches.

As a matter of convenience, transmission networks are often designed in the form of symmetrical lattice structures because the mathematical expressions applying thereto are particularly simple and because this configuration gives the widest possible range of transmission and impedance characteristics obtainable from a symmetrical network. 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, can not be used in unbalanced systems.

A well-known unbalanced equivalent of the symmetrical lattice is a 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 the coupling transformer is eliminated entirely and no mutual inductance is required between the component reactance elements. The network may be made the equivalent of the lattice in its transmission properties but is unbalanced in form, with a consequent saving in the number of elements required. The network of the invention is of the bridged type, comprising a plurality of pairs of series arms and a plurality of shunt branches forming a plurality of T-networks which are connected in parallel, with a single common bridging branch.

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

Fig. 1 is a diagrammatic representation of a network embodying the invention;

Fig. 2 shows diagrammatically the lattice net-

work of which the network of Fig. 1 is the electrical equivalent;

Fig. 3 represents a wave filter designed in accordance with the invention; and

Fig. 4 shows the lattice structure of which the network of Fig. 3 is the unbalanced equivalent.

The network of the invention, as shown diagrammatically in Fig. 1, is of the bridged type comprising a bridging branch Z_1 and a plurality of T-networks connected in parallel at their ends. The network shown in Fig. 1 has three such T-networks, one comprising a pair of equal series arms, Z_2, Z_2 and a shunt branch Z_3 , another consisting of series arms Z_4, Z_4 and a shunt branch Z_5 and the third made up of the series arms Z_6, Z_6 and the shunt branch Z_7 . Although the network shown in the figure comprises only three component T-networks, the invention is not limited to this number. Any number of partial networks of the T-type may be employed, the number required depending in general upon the complexity of the lattice structure of which the bridged-type network is the electrical equivalent.

The network shown in Fig. 1 is the unbalanced equivalent of the lattice network shown in Fig. 2, which comprises 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 may have any degree of complexity and any of a wide variety of schematic forms. For a detailed explanation of how to design a lattice network which will have any desired transmission characteristics reference is made to my prior Patent 1,828,454, issued October 29, 1931.

Proof of the equivalence of the bridged-type network of Fig. 1 to the symmetrical lattice network having the line and diagonal branches shown in Fig. 2 rests upon the conversion of simple lattice structures to their equivalent T-networks. The lattice shown in Fig. 2 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_2 and each diagonal branch consists of Z_2 in series with $2Z_3$. The second lattice has a line impedance Z_4 and a diagonal impedance comprising Z_4 in series with $2Z_5$. The third lattice has Z_6 for the line branch and Z_6 in series with $2Z_7$ for the diagonal branch, and the fourth lattice has a line impedance

$$\frac{1}{2}Z_1$$

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 the Bell System Technical Journal for January 1923. The same equivalence is shown in Figs. 24A and 24B appearing in Appendix B, page 281 of K. S. Johnson's "Transmission Circuits for Telephonic Communication" published by D. Van Nostrand Company.

Applying the process outlined above to the networks under consideration, the simple lattice having Z_6 for the line branch and Z_6 in series with $2Z_7$ for the diagonal branch may be converted into the simple T-network in Fig. 1 having Z_6 for each series arm and

$$\frac{1}{2}(Z_6 + 2Z_7 - Z_6) = Z_7$$

for the shunt arm. The other two simple T-networks of Fig. 1 are obtained in a similar manner. The bridging branch Z_1 may be considered to be a T-network having two series arms each equal to

$$\frac{1}{2}Z_1$$

with an interposed shunt branch infinite in impedance.

It will be observed that the conversion from a lattice to the bridged type network shown in Fig. 1 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 impedance branch Z_x of Fig. 2 consists of an impedance Z_6 and therefore the other branch impedance Z_y is required to have an arm comprising an impedance Z_6 in series with a positive, that is, a physical, impedance $2Z_7$ which latter impedance may, of course, be zero.

The specific application of the network of Fig. 1 is illustrated in the low-pass wave filter of Fig. 3, which is the unbalanced equivalent of the symmetrical lattice shown in Fig. 4 and requires no mutual inductance in its construction. Each line branch of the lattice network of Fig. 4 consists of three parallel arms in one of which are the inductance L_1 and the capacitance C_1 in series, in another is the capacitance C_2 , and in the third the inductance L_2 . Each diagonal branch of the lattice is composed of two arms, one made up of the inductance L_3 and the capacitance C_3 in series, and the other consisting of the capacitance C_4 . In the bridged type network of Fig. 3 the bridging arm is constituted by the inductance $2L_1$ and the capacitance

$$\frac{1}{2}C_1$$

in series; one pair of series arms are formed of the capacitances C_2 , C_2 , the shunt branch associated therewith being a capacitance equal to

$$2 \frac{C_2 C_4}{C_2 - C_4}$$

and the other pair of series arms consist of the

inductances L_2 , L_2 , the associated shunt branch being made up of an inductance equal to

$$\frac{1}{2}(L_3 - L_2)$$

in series with a capacitance equal to $2C_3$. The designations employed in Figs. 3 and 4 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_3 must be equal to or larger in magnitude than L_2 , and the capacitance C_2 must be equal to or larger than C_4 , so that all of the elements of the bridged type network will be physically realizable without using mutual inductance.

The equivalence of the bridged type network shown in Fig. 3 to the lattice of Fig. 4 becomes readily apparent when the relationship of the component impedances to those of Figs. 1 and 2 is pointed out. The impedance Z_1 of Figs. 1 and 2 corresponds to the inductance $2L_1$ connected in series with the capacitance

$$\frac{1}{2}C_1$$

in Fig. 3, Z_2 corresponds to C_2 , Z_3 to the capacitance of value

$$2 \frac{C_2 C_4}{C_2 - C_4}, Z_4 \text{ to } L_2, \text{ and } Z_5$$

corresponds to $2C_3$ in series with an inductance equal to

$$\frac{1}{2}(L_3 - L_2).$$

In Figs. 3 and 4 there are no impedances corresponding to Z_6 and Z_7 . Thus, the T-network in Fig. 3 having the series arms C_2 , C_2 , and the shunt arm

$$2 \frac{C_2 C_4}{C_2 - C_4}$$

is seen to be the unbalanced equivalent of the simple lattice in Fig. 4 having C_2 for each line branch and C_4 for each diagonal branch. Likewise, the T-network in Fig. 3 having L_2 , L_2 as series arms and having a shunt arm consisting of $2C_3$ in series with

$$\frac{1}{2}(L_3 - L_2)$$

is the equivalent of the simple lattice in Fig. 4 comprising L_2 as the line impedances and L_3 in series with C_3 as the diagonal branches.

As an illustrative example, a low-pass filter has been designed which employs elements having the following values:

$$\begin{array}{ll} L_1 = 0.67 \text{ henry} & C_1 = 0.60 \text{ microfarad} \\ L_2 = 0.50 \text{ henry} & C_2 = 1.00 \text{ microfarad} \\ L_3 = 1.33 \text{ henries} & C_3 = 0.75 \text{ microfarad} \\ & C_4 = 0.50 \text{ microfarad} \end{array}$$

It is to be noted that the network of Fig. 3 may be built without using mutual inductance, but if a simple bridged-T structure were employed, mutual inductance would be required.

What is claimed is:

1. A bridged type wave transmission network comprising a bridging branch and a plurality of symmetrical T-networks connected in parallel, said network being the equivalent of a lattice type structure.

2. A wave transmission network comprising four impedance branches arranged in the form of a bridged-T network, and three additional

impedance branches arranged in the form of a T-network, said T-network being connected in parallel with said bridged-T network, terminal for terminal.

5 3. A wave transmission network of the bridged type comprising a bridging branch and a plurality of T-networks connected in parallel, the component impedance branches of said network having such values that said network is the equivalent of a lattice type network.

10 4. A bridged type wave transmission network comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, the outer terminals of each of said pairs of series arms being connected to the outer terminals of said bridging branch, and said shunt branches being connected, respectively, to the mid-points of said pairs of series arms to form a plurality of symmetrical T-networks.

15 5. An unbalanced bridged type wave transmission network comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, the outer terminals of each of said pairs of series arms being connected to the outer terminals of said bridging branch, and said shunt branches being connected, respectively, to the mid-points of said pairs of series arms to form a plurality of symmetrical T-networks.

20 6. A selective wave transmission network of the bridged type comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, said network being the equivalent of a lattice type network.

25 7. An unbalanced wave transmission network of the bridged type comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, said network being the unbalanced equivalent of a lattice type network.

30 8. A bridged type wave transmission network comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, the component impedance elements comprising said network being primarily reactances, and said network being the equivalent of a lattice type network.

35 9. A wave filter of the bridged type comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, said network being the equivalent of a lattice type wave filter.

10. An unbalanced wave filter of the bridged type comprising a bridging branch, a plurality of pairs of series arms and a plurality of shunt branches, said network being the equivalent of a lattice type wave filter.

5 11. A wave transmission network of the bridged-T type 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.

10 12. A wave transmission network having a pair of input terminals and a pair of output terminals, said network comprising an impedance path connected directly between an input terminal and a corresponding output terminal, a plurality of additional impedance paths connected in parallel with said first path, each of said additional paths comprising a pair of equal impedances serially connected, and a number of shunt impedance paths, said number being equal to the number of additional impedance paths connected in parallel with said first path, each of said shunt impedance paths having one terminal separately connected to the common terminal of said pair of equal impedances in one of said additional paths, and having connections from the other terminal of each of said shunt impedance paths to the remaining input and output terminals of said network.

15 13. A wave transmission network having a pair of input terminals and a pair of output terminals comprising a pair of equal impedances connected in series between an input terminal and an associated output terminal, a shunt branch connected to the common terminal of said pair of impedances, a second pair of equal impedances connected in series with each other and in parallel with said first mentioned pair of impedances between the aforesaid input terminal and output terminal, a second shunt branch connected to the common terminal of said second pair of impedances, and a bridging branch connected between the aforesaid input terminal and output terminal.

HENDRIK W. BODE.