May 26, 1942. W. P. MASON 2,284,529

WAVE TRANSMISSION NETWORK

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FIG. 1

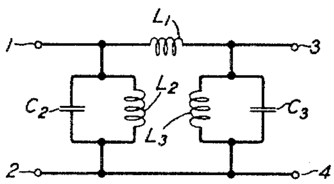



FIG. 2

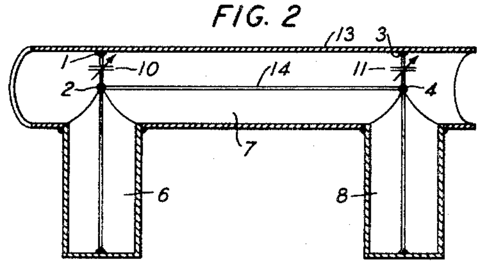



FIG. 3

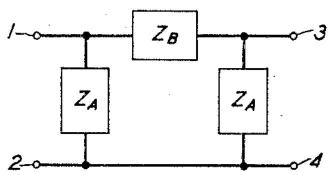



FIG. 4

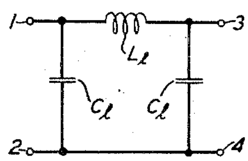



FIG. 5

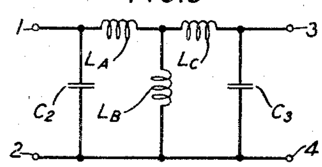



FIG. 6

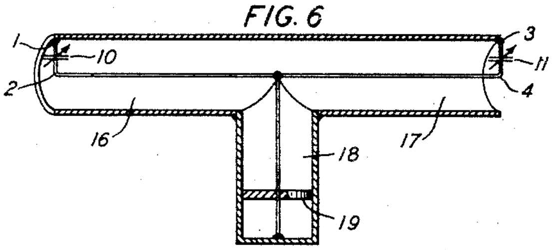



FIG. 7

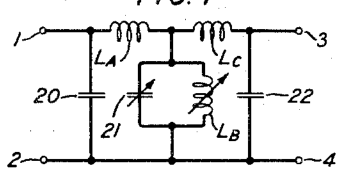



FIG. 8

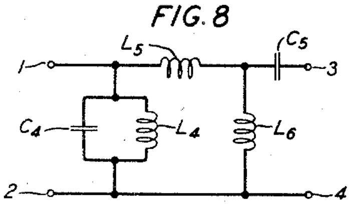



FIG. 9

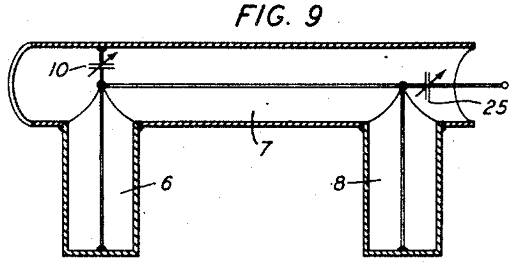



FIG. 10

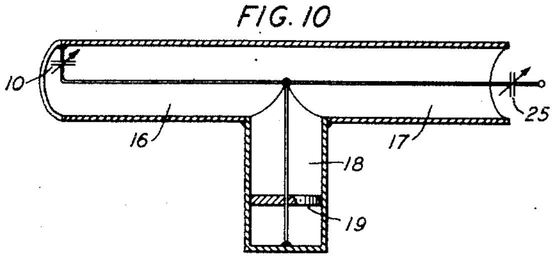
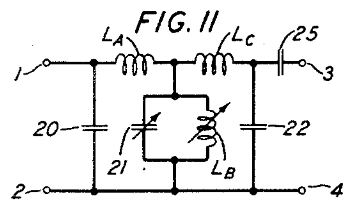



FIG. 11

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WAVE TRANSMISSION NETWORK

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FIG. 12

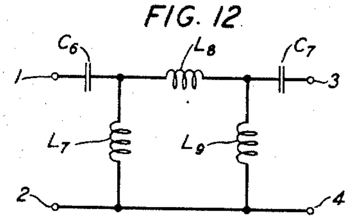



FIG. 13

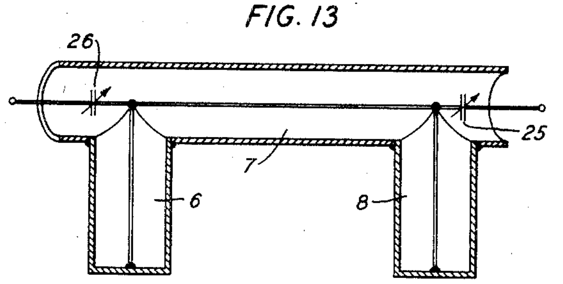



FIG. 14

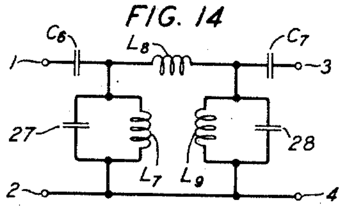



FIG. 16

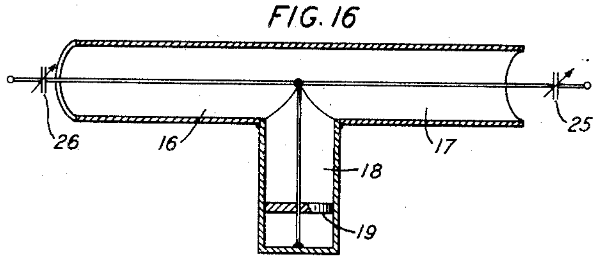



FIG. 15

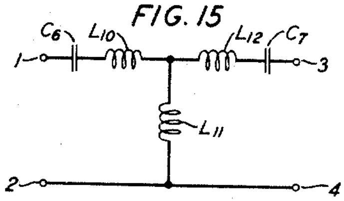



FIG. 17

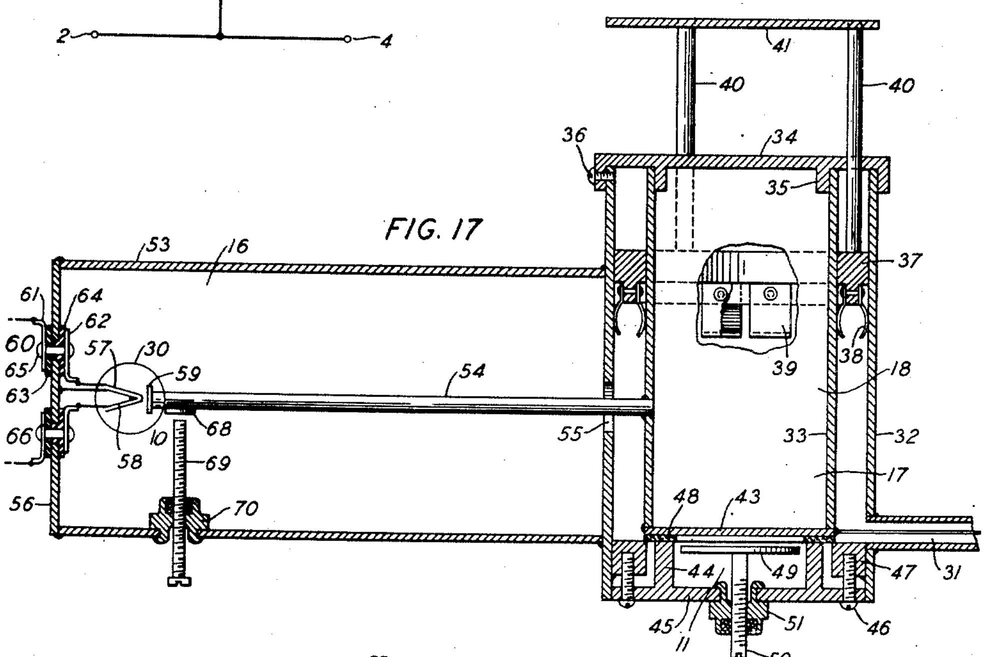
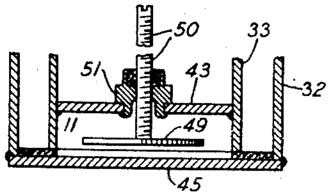



FIG. 18

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2,284,529

# UNITED STATES PATENT OFFICE

2,284,529

## WAVE TRANSMISSION NETWORK

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Application August 4, 1939, Serial No. 288,287

16 Claims. (Cl. 178—44)

This invention relates to wave transmission networks and more particularly to networks adapted to couple loads having different impedances.

An object of the invention is to provide an impedance transforming network suitable for use at high frequencies and capable of transmitting a wide band with uniform ratio of transformation.

Other objects are to control the location and the width of the transmission band in a network of this type.

A further object is to improve the transmission characteristics of such a network when operating between terminal loads which have reactive components.

In accordance with the invention there is provided a wave transmission network adapted to transmit freely a selected band of frequencies with a uniform ratio of impedance transformation for coupling two loads having unequal impedances. The network comprises three sections of transmission line arranged in series-shunt relationship and two end capacitors. Two of the sections of line may be connected in shunt at the ends of the third section, or two sections may be connected in tandem and the third section connected in shunt at their junction. The end capacitors may be connected both in series, both in shunt or one in series and the other in shunt. They may be made variable for tuning the network to pass the desired band of frequencies, and for making allowance for reactive components associated with the load impedances. The length of one or more of the line sections may be made variable for controlling the width of the transmission band. Three types of networks are disclosed, namely, high impedance transformers, low impedance transformers and those which have a high impedance on one end and a low impedance on the other.

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

Fig. 1 is a schematic circuit of a high impedance transforming filter in accordance with the invention;

Fig. 2 shows the physical structure of a r work which has the circuit shown in Fig. 1;

Figs. 3 and 4 show equivalent electrical cuits for a section of transmission line;

Fig. 5 shows an alternative structure for circuit of Fig. 1 in which the π of inductances replaced by a T of inductances;

Fig. 6 shows the mechanical structure for the network of Fig. 5;

Fig. 7 shows the equivalent electrical circuit for the network of Fig. 6;

Fig. 8 shows the circuit of a filter having a high impedance on one end and a low impedance on the other end;

Fig. 9 shows a physical structure for the circuit of Fig. 8;

Fig. 10 shows an alternative physical structure for the network of Fig. 9 in which the π of line sections has been replaced by a T structure;

Fig. 11 shows the equivalent electrical circuit for the structure of Fig. 10;

Fig. 12 shows the circuit of an impedance transforming filter having relatively low impedances at both ends;

Fig. 13 shows the mechanical structure for the filter of Fig. 12;

Fig. 14 shows the equivalent electrical circuit for the network shown in Fig. 13;

Fig. 15 shows an alternative structure for the circuit of Fig. 12 in which the π of inductances is replaced by a T of inductances;

Fig. 16 shows the physical structure for the circuit of Fig. 15;

Fig. 17 shows in more detail the mechanical structure of the filter of Figs. 5 and 6; and

Fig. 18 is a fragmentary showing of an alternative construction for one of the variable capacitors shown in Fig. 17.

First will be considered the high impedance transformers, that is, those whose terminating impedances are higher than the characteristic impedances of the transmission line sections used in their construction. A transformer of this type may be obtained by using shunt anti-resonant branches at both ends of the network. Fig. 1 shows such a circuit in which the shunt branches are coupled by the series inductance $L_1$ to form a series-shunt type network between the input terminals 1, 2 and the output terminals 3, 4. The values of the component inductances and capacitances are given by the following formulas:

$$L_1=\frac{\sqrt{Z_{0_I}Z_{0_0}}}{\pi(f_1+f_2)} \qquad (1)$$

$$L_2=\frac{Z_{0_I}(f_2-f_1)}{\pi(f_1^2+f_2^2)\left[1-\frac{f_2^2-f_1^2}{(f_1^2+f_2^2)\Phi}\right]} \qquad (2)$$

$$L_3=\frac{Z_{0_0}(f_2-f_1)}{\pi(f_1^2+f_2^2)\left[1-\frac{\Phi(f_2^2-f_1^2)}{f_1^2+f_2^2}\right]} \qquad (3)$$

$$C_2=\frac{1}{2\pi(f_2-f_1)Z_{0_I}} \qquad (4)$$

$$C_3=\frac{1}{2\pi(f_2-f_1)Z_{0_0}} \qquad (5)$$

in which $Z_{0_I}$ is the characteristic impedance at the mid-band frequency at the input end, $Z_{0_0}$ represents the same quantity at the output end, $\Phi^2$ is the ratio of $Z_{0_0}$ to $Z_{0_I}$, and $f_1$ is the lower limit and $f_2$ the upper limit of the band of frequencies throughout which the transforming filter will transform without loss.

The circuit of Fig. 1 may be provided by the network shown schematically in Fig. 2 comprising three sections of uniform transmission line and two capacitors. The two sections of line 6 and 8 are short-circuited at their outer ends and at their other ends are connected in shunt at the respective ends of the series line section 7, and the capacitors 10 and 11 are also connected in shunt at the ends of the series section. As illustrated, the sections of line are of the concentric conductor type. Line section 7, for example, has an outer cylindrical conductor 13 and a concentric inner conductor 14. The capacitors may be made variable, for the purposes set forth hereinafter. The input connections may be made at the points marked 1, 2 and the output connections at the points marked 3, 4.

A section of uniform transmission line such as 6, 7 or 8 may be represented by the series-shunt type network shown diagrammatically in Fig. 3 comprising the two shunt impedance branches $Z_A$, $Z_A$ and the interposed series branch $Z_B$. Assuming that the line is dissipationless these impedances will have the values given by the following formulas:

$$Z_A=-jZ_0 \cot \frac{\omega l}{2v} \quad (6)$$

$$Z_B=jZ_0 \sin \frac{\omega l}{v} \quad (7)$$

where

$$Z_0=\sqrt{\frac{L}{C}} \quad (8)$$

$$v=\frac{1}{\sqrt{LC}} \quad (9)$$

$\omega$ is $2\pi$ times the frequency, $l$ is the length of the line and L and C are respectively the distributed inductance and the distributed capacitance of the line per unit length.

If the line lengths are less than one-eighth of a wave-length

$$\cot \frac{\omega l}{2v} \doteq \frac{2v}{\omega l}=\frac{2}{\omega l\sqrt{LC}} \quad (10)$$

and

$$\sin \frac{\omega l}{v} \doteq \frac{\omega l}{v}=\omega l\sqrt{LC} \quad (11)$$

Therefore, substituting in Equations 6 and 7,

$$Z_A=\frac{-2j}{\omega lC} \quad (12)$$

and

$$Z_B=j\omega lL \quad (13)$$

It follows from this that for a line length of less than an eighth wave-length the simplified lumped electrical representation is as shown in Fig. 4 in which each shunt impedance is a capacitance $C_1$ equal in value to half of the total distributed capacitance of the line section and the series impedance is an inductance $L_1$ equal in value to the total distributed inductance of the line. If longer sections are used the values of the impedances in the equivalent circuit may, of course, be found from Formulas 6 and 7. In practice it is found that line lengths less than three-sixteenths of a wave-length are usually to be preferred, because the ratio of the useful inductance $L_1$ to the distributed capacitance $C_1$ is larger than for longer lines, and rapidly becomes smaller as the length of line is extended beyond this value. Smaller values of $C_1$ are desirable because they permit the taking into account of larger capacitances which may be associated with the loads.

The distributed inductance L and the distributed capacitance C of a coaxial conductor, per centimeter, are given by the formulas:

$$L=2 \log_e \frac{b}{a}\times 10^{-9} \text{ henries} \quad (14)$$

$$C=\frac{1.11\times 10^{-12}}{2 \log_e \frac{b}{a}} \text{ farads} \quad (15)$$

where $a$ is the outside diameter of the inner conductor and $b$ is the inside diameter of the outer conductor.

It follows, therefore, from the above analysis that by a proper choice of line lengths and ratios of diameters the $\pi$ of line sections in the network of Fig. 2 may be so designed that its equivalent electrical circuit is the same as that shown in Fig. 1. In practice, however, it is usually found desirable not to supply all of the capacitances $C_2$ and $C_3$ by the distributed capacitance of the line sections, and to make up the difference by means of the shunt capacitors 10 and 11 of Fig. 2. These capacitors are preferably made variable, as indicated by the arrows, in order to permit tuning of the filter to move the transmission band slightly in one direction or the other. Also, the values of the capacitances $C_2$ and $C_3$ may be reduced somewhat from those calculated in order to allow for negative reactive components which may be associated with the load impedances. If these capacitances are properly adjusted the filter will, in effect, be terminated in purely resistive loads and the transmission characteristic will thereby be improved. Making the capacitors 10 and 11 variable permits this adjustment to be made more precisely, as it is sometimes difficult to determine the reactive component of a load prior to its connection to the filter terminals.

Fig. 5 shows another lumped element network circuit which is electrically equivalent to that of Fig. 1. In Fig. 5 the three inductances $L_A$, $L_B$ and $L_C$ are formed into a T which replaces the $\pi$ of inductances made up of $L_1$, $L_2$ and $L_3$ in Fig. 1. The values of the inductances in the T may be found in terms of the inductances in the $\pi$ by applying the following standard conversion formulas:

$$L_A=\frac{L_1L_2}{L_1+L_2+L_3} \quad (16)$$

$$L_B=\frac{L_2L_3}{L_1+L_2+L_3} \quad (17)$$

$$L_C=\frac{L_1L_3}{L_1+L_2+L_3} \quad (18)$$

Under some circumstances it will be found that the inductances in the T arrangement of Fig. 5 have values which are more easily realizable in line sections than are the values called for in the $\pi$ arrangement of Fig. 1.

Fig. 6 shows how the circuit of Fig. 5 may be constructed physically. The T of inductances is furnished by the three sections of concentric conductor transmission lines 16, 17 and 18. Two of the sections, 16 and 17, are connected in tandem and the third section, 18, is short-circuited at its outer end and at its other end is connected in shunt at their junction. The effective length of the shunt section can be varied by moving the annular conducting member 19 in one direction or the other and thereby short-circuiting the line 18 at the desired point.

Fig. 7 shows the equivalent electrical circuit for the T of line sections shown in Fig. 6. In addition to the inductances $L_A$, $L_B$ and $L_C$ the circuit includes the end shunt capacitances 20 and 22 and the capacitance 21 in shunt with $L_B$. The capacitances 20 and 22 form parts of the capacitances $C_2$ and $C_3$, respectively, of Fig. 5. By proper design the capacitance 21 can be made so small that, at the mid-band frequency of the filter, its impedance is large compared to that of the inductance $L_B$, and therefore the effect of this capacitance may be neglected.

The network of Fig. 6 is completed by the addition of the shunt end capacitors 10 and 11. The capacitor 10 will have a capacitance equal to $C_2$ minus the capacitance 20. The capacitor 11 will have a capacitance equal to $C_3$ minus the capacitance 22. In each case allowance should be made for any reactive component which may be associated with the load impedance. As explained above, the capacitors 10 and 11 may be made variable for tuning the filter to pass the desired band. By adjusting the effective length of the line section 18 the width of the transmission band may be controlled.

Fig. 8 is the circuit of an impedance transforming filter which may be designed to have a high impedance at the input end, represented by terminals 1, 2, and a low impedance at the output end, represented by terminals 3, 4. The circuit is characterized by an anti-resonant shunt branch comprising $C_4$ and $L_4$ at the input end and a series capacitance $C_5$ at the output end. The values of the component elements may be found from the following formulas:

$$L_4=\frac{Z_{0_I}(f_2-f_1)}{2\pi f_1 f_2\left[1-\frac{(f_2-f_1)^2(1-\Phi)}{f_1 f_2 \phi}\right]} \qquad (19)$$

$$L_5=\frac{\sqrt{Z_{0_I}Z_{0_0}}}{2\pi(f_2-f_1)} \qquad (20)$$

$$L_6=\frac{Z_{0_0}}{2\pi(f_2-f_1)(1-\Phi)} \qquad (21)$$

$$C_4=\frac{1}{2\pi(f_2-f_1)Z_{0_I}} \qquad (22)$$

$$C_5=\frac{f_2-f_1}{2\pi f_1 f_2 Z_{0_0}} \qquad (23)$$

Fig. 9 shows a network which will provide the circuit of Fig. 8. The structure of Fig. 9 is the same as that shown in Fig. 2 except that the shunt capacitor 11 at the output end is replaced by a series capacitor 25. Part of the distributed capacitances of the series line 7 and the shunt line 8 will appear in parallel with the inductance $L_6$. However, the effect of this capacitance may be compensated for by decreasing $L_6$ to such a value that, at the mid-band frequency of the filter, the impedance of the parallel combination of $L_6$ and the capacitance is equal to the former impedance of $L_6$ alone.

The $\pi$ of inductances consisting of $L_4$, $L_5$ and $L_6$ in Fig. 8 may be transformed into an equivalent T of inductances by means of the Formulas 16, 17 and 18. The T of inductances may be provided by the network structure shown in Fig. 10 which is the same as that of Fig. 6 except the shunt capacitor 11 is replaced by a series capacitor 25. Fig. 11 shows the equivalent circuit of the T of line sections and the series capacitor 25. The circuit for the line sections is the same as that given in Fig. 7. In Fig. 11 it is seen that there are two extra capacitances, 21 and 22, which are not found in the circuit of Fig. 8. The effect of the capacitance 21 may be allowed for by decreasing the value of $L_B$ until the impedance of the parallel combination of $L_B$ and the capacitance 21 is the same, at the mid-band frequency, as is the former impedance of $L_B$ alone. Since the capacitance of the series capacitor 25 is ordinarily large compared to the shunt capacitance 22, the principal effect of the latter is to decrease slightly the ratio of impedance transformation for the filter.

Fig. 12 shows a circuit capable of stepping down from the impedance of a transmission line to a very low impedance. The filter comprises the $\pi$ of inductances made up of $L_7$, $L_8$ and $L_9$ and the series end capacitances $C_6$ and $C_7$. The values of the component elements may be found from the following formulas:

$$L_7=\frac{Z_{0_I}f_1 f_2}{\pi(f_2-f_1)(f_1^2+f_2^2)\left[1-\frac{f_2^2-f_1^2}{\Phi(f_1^2+f_2^2)}\right]} \qquad (24)$$

$$L_8=\frac{f_1 f_2\sqrt{Z_{0_I}Z_{0_0}}}{\pi(f_2-f_1)(f_2^2-f_1^2)} \qquad (25)$$

$$L_9=\frac{Z_{0_0}f_1 f_2}{\pi(f_2-f_1)(f_1^2+f_2^2)\left[1-\frac{\Phi(f_2^2-f_1^2)}{f_1^2+f_2^2}\right]} \qquad (26)$$

$$C_6=\frac{f_2-f_1}{2\pi f_1 f_2 Z_{0_I}} \qquad (27)$$

$$C_7=\frac{f_2-f_1}{2\pi f_1 f_2 Z_{0_0}} \qquad (28)$$

Fig. 13 shows the physical structure for the circuit of Fig. 12. The network is similar to the one shown in Fig. 9 except that the shunt capacitor 10 has been replaced by the series capacitor 26. The equivalent electrical circuit is given in Fig. 14, which differs from Fig. 12 by including the capacitances 27 and 28, shunting the inductances $L_7$ and $L_9$, respectively. The values of these inductances can be decreased to compensate for the effect of these capacitances, as explained above in connection with the capacitance 21 in Fig. 11.

Fig. 15 shows the alternative circuit for that of Fig. 12 employing a T of inductances $L_{10}$, $L_{11}$ and $L_{12}$. The values of these inductances may be found from those of the inductances $L_7$, $L_8$ and $L_9$ by means of the conversion Formulas 16, 17 and 18. The physical structure comprising a T assembly of line sections is shown in Fig. 16. There will be a capacitance in shunt with the central inductance $L_{11}$ contributed by the distributed capacitance of the line sections 16, 17 and 18 which may be compensated for by an adjustment of the value of $L_{11}$ as explained above in connection with Fig. 11. The distributed capacitances of the line sections 16 and 17 will also contribute two shunt capacitances appearing effectively in shunt at the outer ends of the inductors $L_{10}$ and $L_{11}$ which will slightly modify the transformation ratio of the filter, as already explained in connection with the capacitance 22 in Fig. 11.

A specific example of an impedance transforming filter in accordance with the circuit of Fig. 5 and the structure of Fig. 6 will now be considered. The preferred physical embodiment is shown in Fig. 17. It is assumed that the diode **30** having a resistive impedance of 1500 ohms and an effective shunt capacitance of 1 micro-microfarad is to be coupled to a concentric conductor transmission line **31** having a characteristic impedance of 70 ohms. The lower cut-off frequency $f_1$ is to be 430 megacycles and the upper cut-off $f_2$ is 470 megacycles. The values of the end shunt capacitances $C_2$ and $C_3$ are found from Formulas 4 and 5. The values of the inductances $L_1$, $L_2$ and $L_3$ for the form shown in Fig. 1 are found from Formulas 1, 2 and 3 and the values of the inductances $L_A$, $L_B$ and $L_C$ for the T form in Fig. 5 are obtained by applying the transformation Formulas 16, 17 and 18. The values of these elements for the circuit of Fig. 5 are tabulated below.

$C_2=2.65$ micro-microfarads
$C_3=56.8$ micro-microfarads
$L_A=46.3\times 10^{-9}$ henries
$L_B=0.909\times 10^{-9}$ henry
$L_C=1.30\times 10^{-9}$ henries

As a matter of convenience in construction the two line sections **17** and **18** are chosen of the same impedance and, therefore, may be constructed with outer conductors of the same inside diameter and inner conductors of the same outside diameter. Furthermore, these two sections are arranged in axial alignment, with a continuous cylindrical outer conductor **32** and a continuous cylindrical concentric inner conductor **33**. The outer conductor **32** has an inside diameter of 2 inches and the inner conductor has an outside diameter of 1.5 inches. The line section **17** has a length of 1 inch and the section **18**, which is variable, has a maximum length of about 1 inch. The inner conductor **33** is supported from the end plate **34** by means of the annular flange **35** to which the conductor is securely attached. Screws such as **36** hold the end plate in place. The conductors are made of aluminum, brass or other metal of good conductivity.

The outer end of the line **18** is short-circuited at the required point by means of the annular metallic member **37** having fastened thereto a number of springs, such as **38** and **39**, which contact both the inner and outer conductors. The short-circuiting member **37** may be moved in or out by means of the three push rods **40** which are fastened at one end to the member **37** and at the other end to the disc **41** which is preferably made of insulating material. The effective length of the line section **18** may therefore be adjusted by sliding the member **37** in or out. For the filter under consideration the effective length of the line **18** is about 0.62 inch.

At the outer end of the line section **17** is the shunt capacitor **11** which has a fixed portion and a variable portion. The fixed portion consists of the capacitance between the end plate **43** of the inner conductor **33** and the annular flange **44** on the end plate **45** of the outer conductor **32**. The mica ring **48** serves as a separator, and its high dielectric constant increases the capacitance. The end plate **45** is held in position by means of screws such as **46** which screw into shoulders such as **47** secured to the inside of the outer conductor **32**.

The variable portion of the capacitor **11** consists of the capacitance between the end plate **43** and the metal disc **49** secured to the inner end of the screw **50** which projects through a hole in the end plate **45** and is locked in adjustment by means of the clinch nut **51** inserted in the hole. As the screw **50** is turned by means of the screw-driver slot in its end the disc **49** is moved nearer to or further away from the end plate **43** and the capacitance is thereby varied. Fig. 18 shows an alternative construction for the variable portion of the capacitor **11** in which the screw **50** extends in the opposite direction and the clinch nut **51** is inserted in a hole in the end plate **43** associated with the inner conductor **33**. This screw may be extended, if desired, to project through the end plate **34**. In this case the variable capacitance is that effective between the disc **49** and the end plate **45**.

The line section **16** has a cylindrical outer conductor **53** with an inner diameter of 2 inches and a concentrically positioned inner conductor **54** with an outer diameter of ⅛ inch. The inner end of the inner conductor **54** extends through a hole **55** in the outer conductor **32** and is conductively attached to the inner conductor **33**. The inner end of the outer conductor **53** is soldered, welded or brazed to the side of the outer conductor **32**. The outer end of conductor **53** is extended and closed with the end plate **56** to provide a shielded compartment for the thermionic device **30** which has a cathode **57**, a heater element **58** and a plate **59**. The length of the inner conductor **54**, measured from the point of attachment to the conductor **33** to the plate **59**, is theoretically 3.86 inches but this may be shortened somewhat to allow for the capacitance and inductance associated with the wiring to the tube, or for similar effects.

Electrical connection to the cathode **57** is made through the capacitor **60** which comprises an outer metal plate **61**, an inner metal plate **62**, a separator **63** and a second separator **64** having a portion which serves as an insulating bushing. The two plates **61** and **62** are held in place by the rivet **65**. Connection to the heater element **58** is made through a capacitor **66** having a construction similar to that of the capacitor **60**.

The variable capacitor **10** is constituted by the metallic disc **68** attached to the inner conductor **54** near its outer end and the screw **69** which threads through the clinch nut **70** inserted in the wall of the outer conductor **53**. As the screw **69** is turned the spacing between its end and the disc **68** is varied and a variable capacitance is thus provided.

In the filter of Fig. 17, for the dimensions given, the line section **16** will provide an inductance $L_A$ of $46.3\times 10^{-9}$ henries with a shunt capacitance of 1.06 micro-microfarads at each end. The line section **17** will furnish an inductance $L_C$ of $1.30\times 10^{-9}$ henries with a shunt capacitance of 2.17 micro-microfarads at each end. The line section **18** provides an inductance $L_B$ of $0.909\times 10^{-9}$ henry shunted by a capacitance of 1.52 micro-microfarads. In the equivalent circuit of Fig. 7, therefore, the capacitance **21** will have a value of 4.75 micro-microfarads. However, at the mid-band frequency this capacitance will have an impedance which is about thirty times the impedance of the inductance $L_B$ and therefore the effects of the capacitance **21** may be neglected.

Assuming that the diode **30** has an effective shunt capacitance of 1 micro-microfarad then the capacitance to be supplied by the variable capacitor 10 will be

$$2.65-1.06-1=0.59 \text{ micro-microfarad}$$

The capacitance to be furnished by the capacitor 11 will be

$$56.80-2.17=54.63 \text{ micro-microfarads}$$

For the line sections 17 and 18 the characteristic impedance is 17.3 ohms and for the section 16 it is 166.5 ohms.

In operation, the filter shown in Fig. 17 can be accurately tuned to pass the desired band of frequencies by manipulating the screws 50 and 69, and the width of the transmission band may be regulated by sliding the short-circuiting member 37 in or out.

What is claimed is:

1. A wave transmission network for transmitting with substantially uniform ratio of impedance transformation a selected band of frequencies between two loads having unequal impedances comprising three sections of uniform transmission line arranged in series-shunt relationship and two capacitors connected at the respective ends of said arrangement of line sections.

2. A network in accordance with claim 1 in which each of said sections of line has a length equal to less than three-sixteenths of the wavelength corresponding to the upper limit of said band of frequencies.

3. A network in accordance with claim 1 in which two of said sections of line are connected in shunt at the respective ends of the third section.

4. A network in accordance with claim 1 in which two of said sections of line are connected in tandem and the third section is connected in shunt at their junction.

5. A network in accordance with claim 1 in which said capacitors are connected in series.

6. A network in accordance with claim 1 in which one of said capacitors is connected in shunt and the other of said capacitors is connected in series.

7. A network in accordance with claim 1 in which means are provided for varying the effective length of one of said sections of line.

8. A network in accordance with claim 1 in which two of said sections of line are connected in tandem, the third section is connected in shunt at their junction and said capacitors are connected in shunt.

9. A network in accordance with claim 1 in which two of said sections of line are connected in tandem, the third section is connected in shunt at their junction, said capacitors are connected in shunt and means are provided for varying the effective length of said third section.

10. A network in accordance with claim 1 in which two of said sections of line are connected in tandem, the third section is connected in shunt at their junction, said capacitors are connected in shunt, means are provided for varying the effective length of said third section and means are provided for varying the capacitances of said capacitors.

11. A network in accordance with claim 1 in which two of said sections of line are connected in shunt at the respective ends of the third section, one of said capacitors is connected in series and the other of said capacitors is connected in shunt.

12. A network in accordance with claim 1 in which two of said sections of line are connected in shunt at the respective ends of the third section and said capacitors are connected in series.

13. A wave transmission network for transmitting with substantially uniform ratio of impedance transformation a selected band of frequencies between two loads having unequal impedances comprising a section of uniform transmission line so connected as to permit the transmission of energy from one end to the other, two other sections of uniform transmission line connected with said first-mentioned section of line to form a series-shunt arrangement and two capacitors connected at the respective ends of said arrangement of the sections.

14. A network in accordance with claim 13 in which said capacitors are connected in shunt.

15. A network in accordance with claim 13 in which one of said capacitors is made variable.

16. A network in accordance with claim 13 in which both of said capacitors are made variable.

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