April 9, 1940.

H. O. PETERSON

2,196,272

TRANSMISSION NETWORK

Filed July 25, 1934

3 Sheets-Sheet 1

Fig. 1

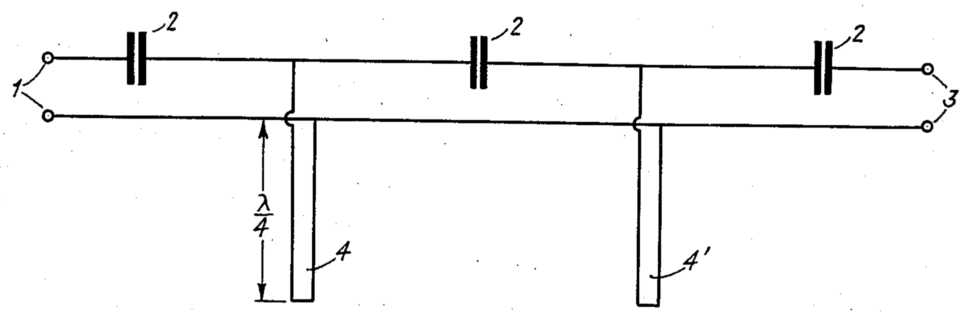


Fig. 2

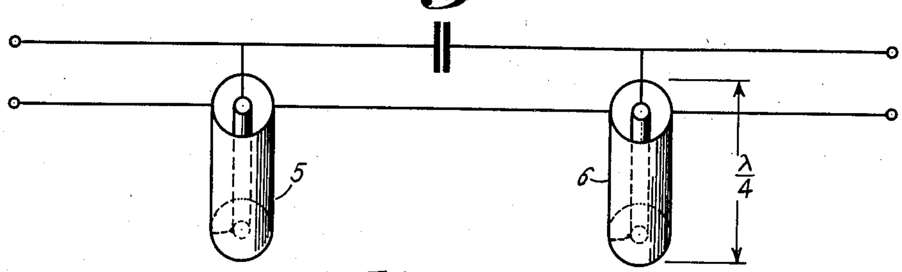


Fig. 3

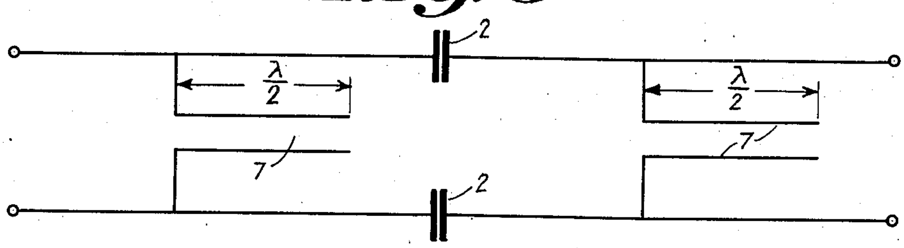
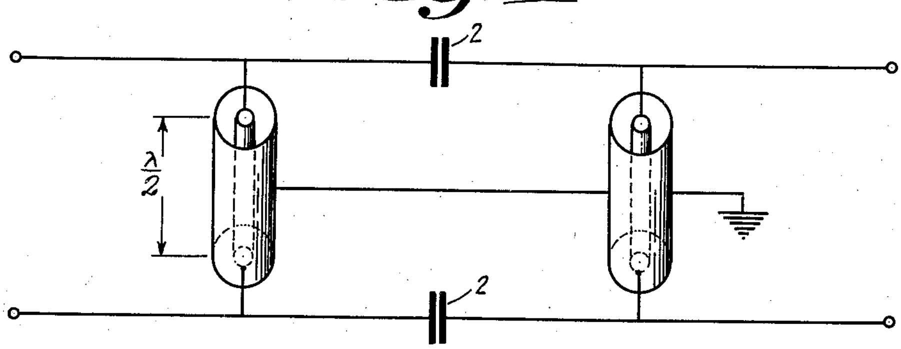


Fig. 4



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TRANSMISSION NETWORK

Filed July 25, 1934 3 Sheets-Sheet 2

Fig. 5

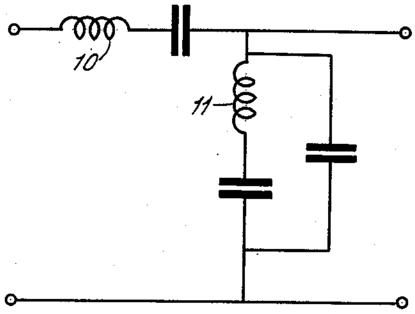


Fig. 5a

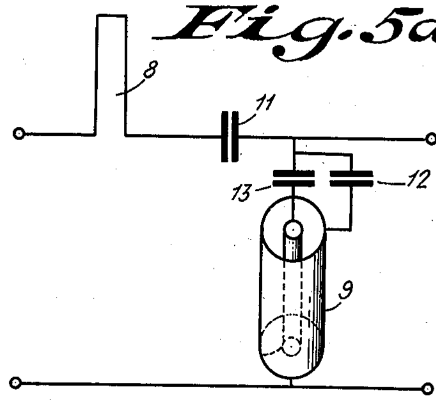


Fig. 6

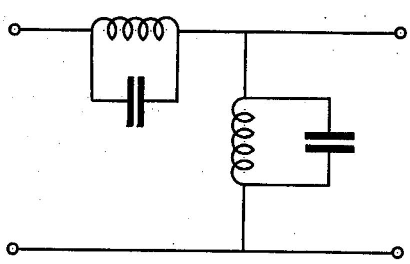


Fig. 6a

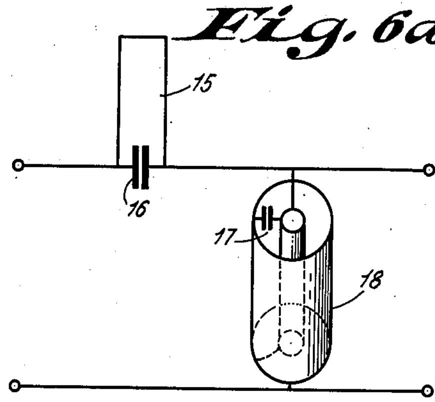


Fig. 7

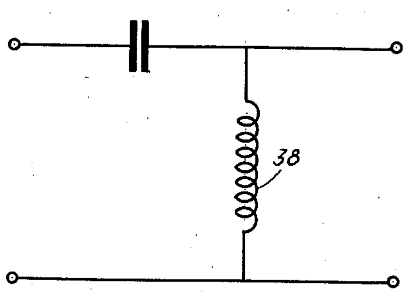
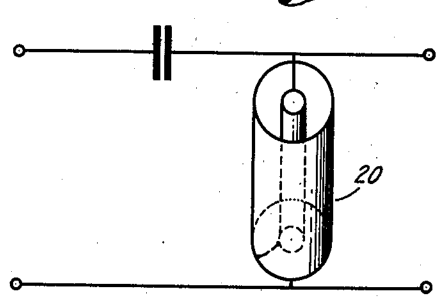


Fig. 7a



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April 9, 1940. H. O. PETERSON 2,196,272
TRANSMISSION NETWORK
Filed July 25, 1934 3 Sheets-Sheet 3

Fig. 8

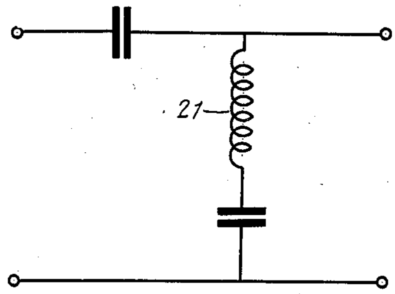


Fig. 8a

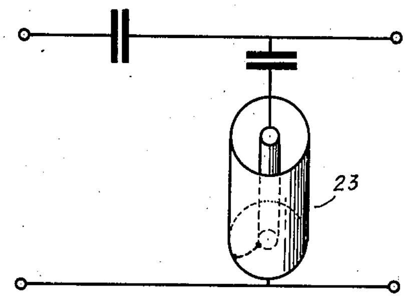


Fig. 9

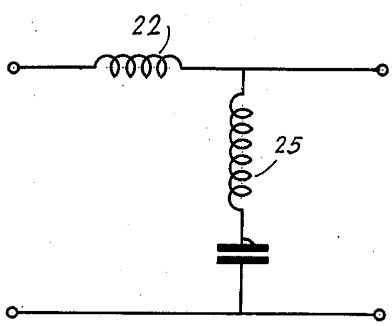


Fig. 9a

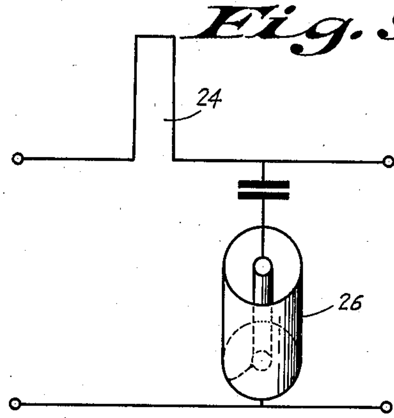


Fig. 10

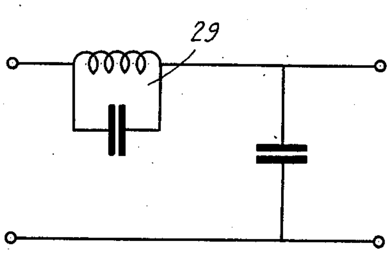
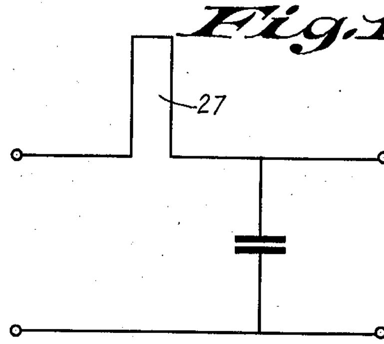


Fig. 10a



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Patented Apr. 9, 1940 2,196,272

UNITED STATES PATENT OFFICE

2,196,272

TRANSMISSION NETWORK

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Application July 25, 1934, Serial No. 736,887

5 Claims. (Cl. 178—44)

This invention relates to transmission networks, and particularly to selective wave filters.

In the construction of networks, such as wave filters, it is customary to employ a combination of resistances, inductances and condensers, or any two of these, to obtain a selective conductor which enables the passage of one or more frequencies better than it does others, and it is known to be desirable to utilize inductors and capacitors which have minimum power factors.

One of the objects of the present invention is to provide a wave filter with an extremely low power factor, and this is achieved in accordance with the invention by the employment of a section of transmission line as a substitute for a lumped inductor and/or capacitor in certain branches of networks.

An important advantage of the present invention is that it is immaterial what type of transmission line is used as a section of a network, although it is preferred to use concentric transmission lines, due, in part, to their non-radiating characteristics.

According to one particular feature of the invention, any quarter wave section of transmission line or odd multiple thereof may be used as a parallel tuned circuit in a filter network, and, according to another feature of the invention, any half wave section of transmission line or odd multiple thereof may be used as a series or parallel tuned circuit in a filter network, depending upon whether the half wave length line is short circuited or open at the far end. Of course, two one-quarter wave line sections may be used as a substitute for a half wave section, although it is preferred to use a minimum number of quarter wave sections.

The present invention finds particular use in certain types of high pass and low pass filters wherein series tuned circuits comprising inductors and capacitors are used as shunt elements to eliminate certain frequencies. These tuned circuits may be replaced by half wave sections of transmission line in accordance with the principles of the present invention.

A better understanding of the invention may be had by referring to the following detailed description, which is accompanied by drawings wherein:

Figs. 1 and 2 illustrate, by way of example only, a band pass filter section provided with quarter wave transmission line sections in accordance with the present invention;

Figs. 3 and 4 show wave filters provided with half wave transmission line sections;

Figs. 5–10, inclusive, illustrate various types of known filter networks (such known filters are shown, for example, in Shea's book on "Transmission Networks and Wave Filters," published 1930, New York, by Van Nostrand Company, pages 317, 318 and 254, to which reference is herein made); and

Figs. 5*a*–10*a*, inclusive, respectively show the equivalent networks for Figs. 5–10, in accordance with the principles of the invention.

Referring to Fig. 1 in more detail, which shows two sections of a mid-series type filter, there is shown one form of high band pass filter comprising a plurality of serially connected condensers 2 which are located in series between the terminals 1 and 3. In shunt relation with respect to the filter are two sections of transmission line 4 and 4′, each of which consists of a two-conductor line, the individual wires of which are each one-quarter of a wave length long, as shown. As is well known, such a transmission line forms a path of high impedance to the operating wave length and thus acts in a manner similar to the well known parallel tuned circuit comprising inductance and capacitance in parallel relationship.

By suitable design of the physical length and distributed capacity and inductance per unit length of the transmission line sections used as recurrent elements in the electric wave filter, it is possible to govern the impedance versus frequency characteristics to the end that the impedances of shunt and series elements of the wave filter will have proper relationships to give band pass characteristics at certain desired frequency ranges.

Fig. 2 shows another type of band pass filter. In this case there are provided concentric transmission line sections 5 and 6, which are in this case approximately one-quarter wave length long, or an odd multiple of quarter wave lengths long for the frequencies lying within the pass band of the filter. In this arrangement, the inner conductor is connected to one line of the filter and the outer conductor to the other line of the filter, both conductors being shunted or connected together at the bottom. The connection between the two conductors is generally achieved by means of a solid metallic disc across the inner and outer conductors.

Fig. 3 shows a modification of the same type of band pass filter as Fig. 2, in which the shunt elements 7 are approximately one-half wave length long at the band pass frequencies. Since a half wave length section of line is used, the impedance at the near end to the operating wave length approximates that across the far end of the line section. In this case line 7 is open-ended and consequently it is a path of high impedance to the operating wave length and simulates a parallel tuned circuit. If line 7 were short circuited at the far end, it would simulate a series tuned circuit in respect to the desired wave length. Condensers 2, of course, are coupling condensers. The line sections 7 may or may not be shielded, as desired, and it is preferred to so shield the elements of the wave filter.

Fig. 4 is a modification of Fig. 3, in which concentric transmission line elements are used as shunt sections. In this case the line sections are approximately one-half wave length long at the band pass frequencies, the outer conductors of each line section being grounded as shown in the drawings, in order to obtain a better shielding effect. It is to be understood, however, that it is not necessary that the outer conductors be shielded.

It should be noted that in Figs. 1, 2, 3 and 4 there is a difference in the number of condenser elements shown. This is merely because of a difference in the manner of termination. A filter section may be terminated either in the middle of a series element or in the middle of a shunt element. Fig. 1 shows a section terminated in the middle of the series elements whilst Fig. 2 shows the mid shunt form of termination. The mid series termination is sometimes called a T section and the mid shunt termination is sometimes called a π section. This is explained on pages 164–166 of "Communication Engineering," by Everitt, and elsewhere. Accordingly, if desired, condensers may be placed on the other sides of the shunt elements in Figs. 2, 3 and 4.

Fig. 5 shows another type of band pass filter section made up in its well known form of inductor and capacitor elements, and Fig. 5*a* shows the equivalent network. In this case the individual conductors of the line sections 8 and 9 are short-circuited at the far end and made considerably shorter than one-quarter of a wave length as a matter of general practice, so that they constitute inductance elements having values similar to 10 and 11 of Fig. 5. The filter of Fig. 5 follows well known filter network theory and is described in Shea on "Transmission Networks and Wave Filters," published 1930, by Van Nostrand Company, New York, page 318.

Fig. 6 shows another form of band pass filter section and opposite it its equivalent network 6*a*. In Fig. 6*a*, elements 15 and 18 are also considerably shorter than one-quarter wave length and short-circuited at the far end, so that these constitute inductance elements. It will be noted that a condenser 17 is provided to bridge the inner and outer conductors of the concentric transmission line section 18, and a condenser 16 bridges line section 15. If these condensers were not provided, then, in order to have them function as parallel tuned circuits similar to those shown in Figs. 1 and 2, it would be necessary to make the transmission line sections as quarter wave length lines. The filter of Fig. 6 and the theory underlying same are referred to by Shea, supra, on page 317.

Fig. 7 shows a simple high pass filter, and 7*a* its equivalent network. These two figures indicate how a network may be built up with transmission line elements in accordance with the invention. In this case also, transmission line 20 is considerably shorter than one-quarter of a wave length at operating frequencies and short circuited at its bottom so as to be equivalent to an inductor.

Fig. 8 represents a typical high pass filter section of the usual form and 8*a* its equivalent network. Here again the transmission line section 23 is considerably less than one-quarter of a wave length long and short circuited in order to simulate the characteristics of inductor 21 of Fig. 8.

Fig. 9 shows a typical low pass filter section and Fig. 9*a* shows its equivalent made up with transmission line sections. Inductor 22 is herein replaced by a short circuited transmission line section 24, and inductor 25 by a transmission line section 26. Both 24 and 26 are, of course, shorter than a one-quarter wave length.

Fig. 10 illustrates another typical low pass section wherein the parallel tuned circuit 29, 30 has been replaced in the equivalent network of Fig. 10*a* by a transmission line section 27, which is approximately one-quarter wave length long at the frequency to which 29 and 30 would resonate.

The filters of Figs. 7, 8, 9 and 10 are shown on page 254 (Fig. 139) of Shea, supra.

From the foregoing it will be evident that a large number of modifications and combinations can be drawn by following the principles underlying the invention. The embodiments described have been given merely for purposes of illustration, in order to show some of the more commonly used networks and their equivalent circuits. The invention, of course, is not limited to the precise arrangements illustrated since, as mentioned above, various modifications may be made without departing from the spirit and scope thereof.

By the term "integral multiple" used in the appended claims it is to be understood that I mean any such multiple including unity.

What is claimed is:

1. An electrical wave filter comprising a wave transmission line having two paths, a condenser in series with one of said paths and a concentric transmission line on each side of said condenser comprising inner and outer conductors across said paths, said inner conductors being connected at one end to one path of said wave transmission line and said outer conductors being connected at said same end to the other path of said line, said inner and outer conductors being open ended at said same end, said concentric conductors being approximately one-quarter of a wave length long and short circuited at their other ends, the constants of the condenser with respect to those of the concentric conductors being so proportioned that the wave filter will pass oscillations of at least one desired frequency.

2. An electrical wave filter comprising a wave transmission line of recurrent structure, the recurrent series elements of said line being composed of condensers, and the recurrent shunt elements being composed of transmission line sections having uniformly distributed capacity and inductance per unit length, the lengths and constants of the shunt elements, and the capacitances of the series elements being so proportioned with respect to one another that the electrical wave filter will have pass bands at certain desired frequencies, said recurrent shunt elements consisting of line sections approximately integral multiples of one-half wave length in length for the frequencies lying within the pass bands of the wave filter, said line sections each being connected at only one end to said wave transmission line and being open circuited at the

ends opposite to the ends which connect with the wave transmission line.

3. An electric wave filter consisting of a wave transmission line symmetrically arranged with respect to ground and of recurrent structure, having two series paths consisting of recurrent condensers, and shunt paths comprised of concentric line sections having inner and outer conductors approximately integral multiples of one-half wavelength long for the pass band frequencies of the filter, the opposite ends of the inner conductors of said line sections being connected to opposite series paths at points between recurrent condensers and the outer conductors being connected to a neutral conductor, the impedance versus frequency characteristics of the series and shunt elements being so related to each other that uniform pass bands will be obtained at desired frequencies.

4. A wave filter in accordance with claim 3, characterized in this that said neutral conductor is grounded.

5. An electric wave filter comprising a wave transmission line of recurrent structure, the recurrent sections being composed of series and shunt elements, a series element consisting of a loop of transmission line and a condenser, and a shunt element consisting of a section of concentric transmission line having inner and outer conductors open circuited at one end and short circuited at the other end, said shunt element having a length considerably less than one-quarter wavelength for the frequencies at which it is desired to operate the wave filter, and two condensers connected in series across the open ends of the conductors of the concentric transmission line section with the junction point between these two condensers connected to one side of the wave transmission line, and the short circuited end of the concentric transmission line connected to the other side of the wave transmission line, the impedance versus frequency characteristics of the series and shunt elements being so related between themselves that a band pass characteristic is obtained at certain desired frequencies.

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