

Nov. 12, 1940.

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2,220,922

ELECTRICAL WAVE FILTER

Filed March 17, 1938

5 Sheets-Sheet 1

Fig. 1

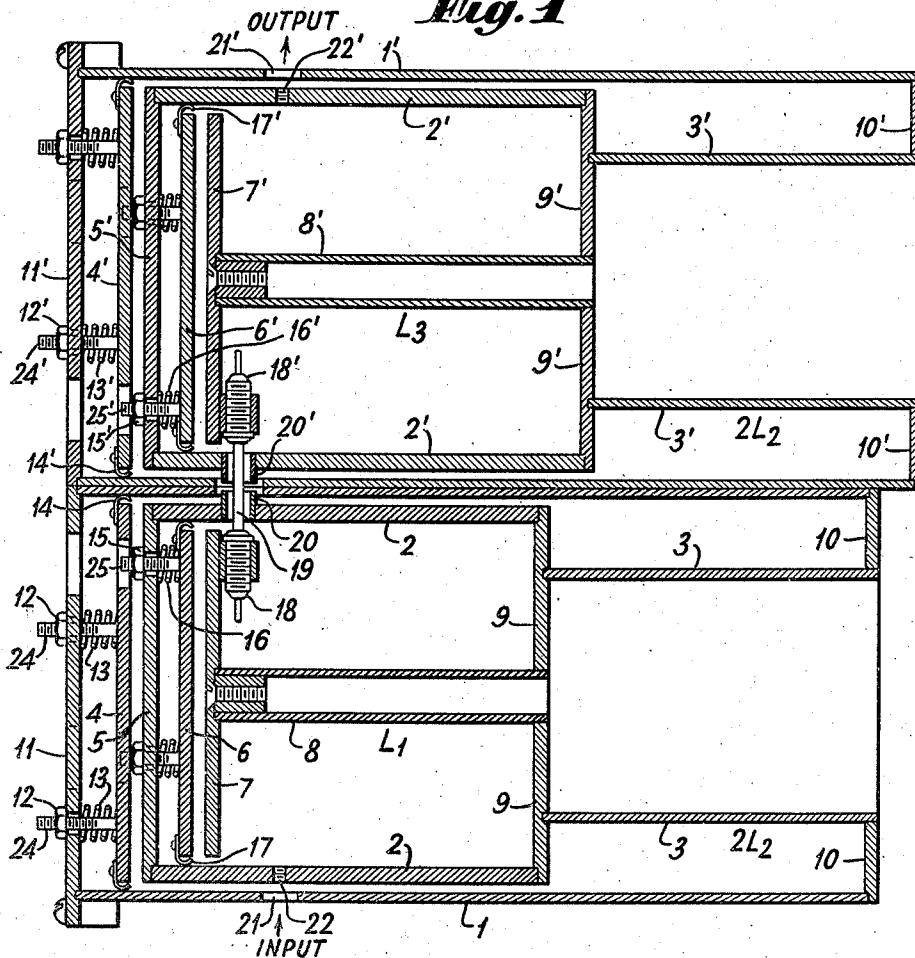
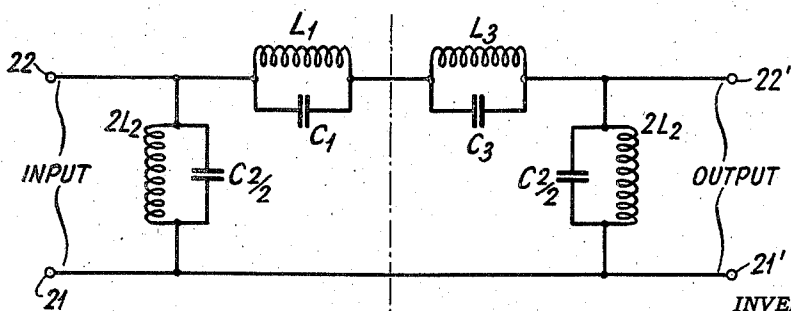


Fig. 1a



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Fig. 2

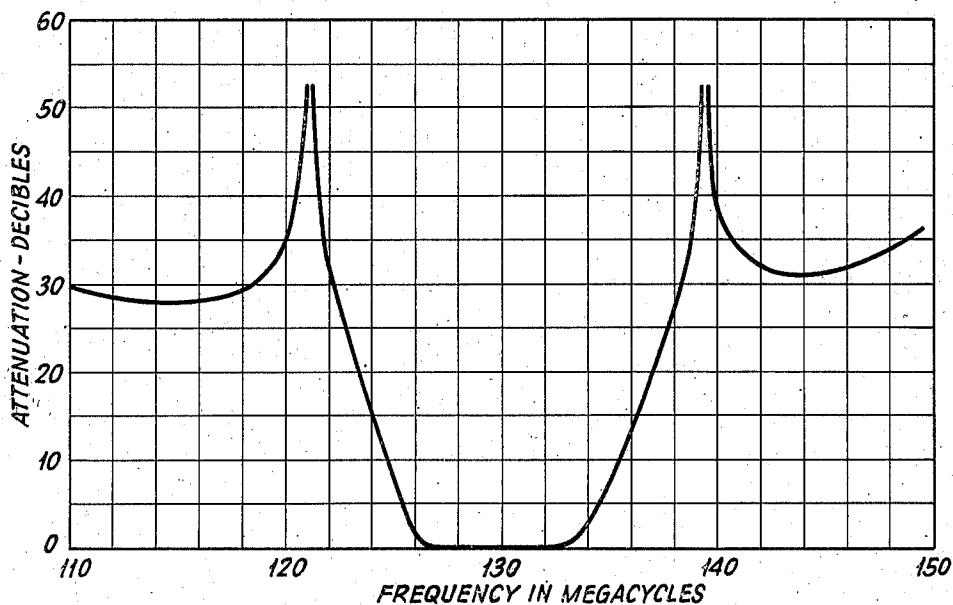


Fig. 3

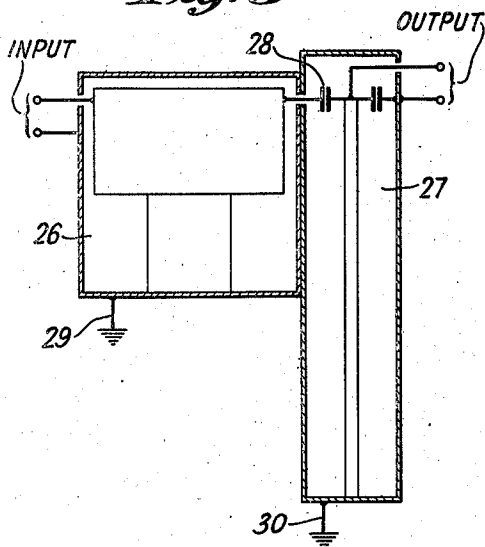
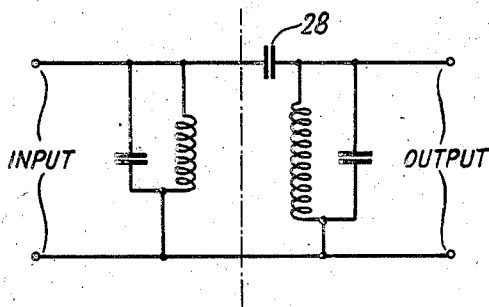


Fig. 4



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Fig. 5

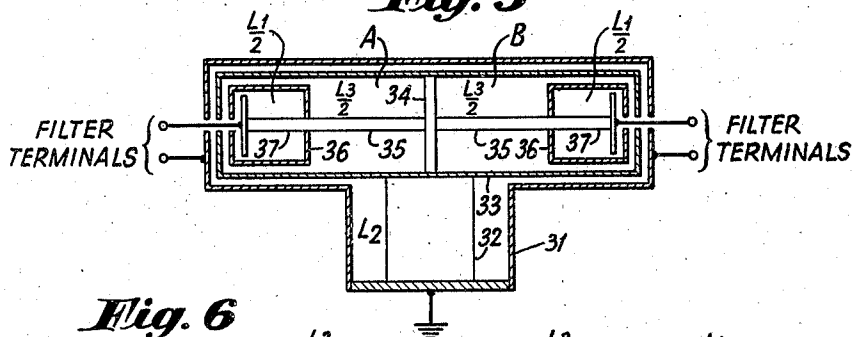


Fig. 6

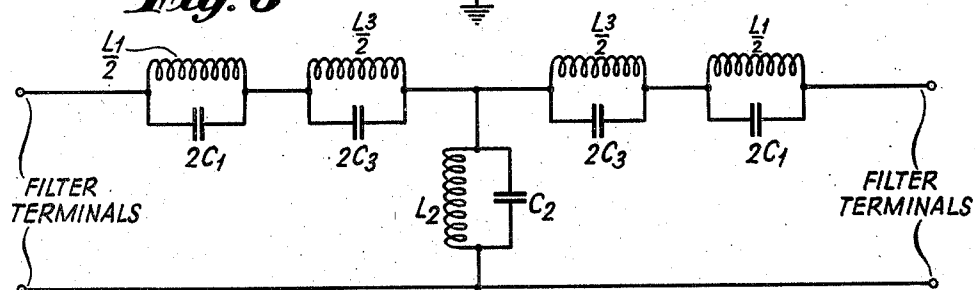


Fig. 8

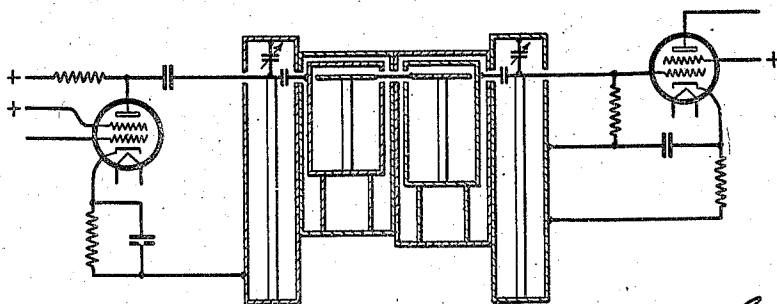
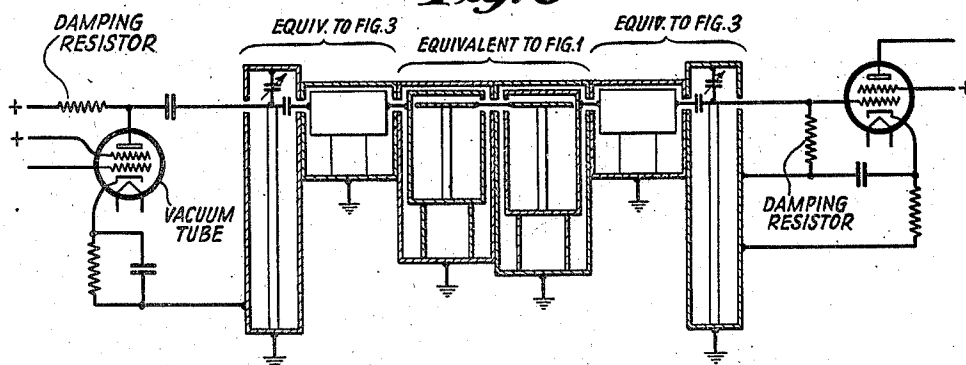


Fig. 9

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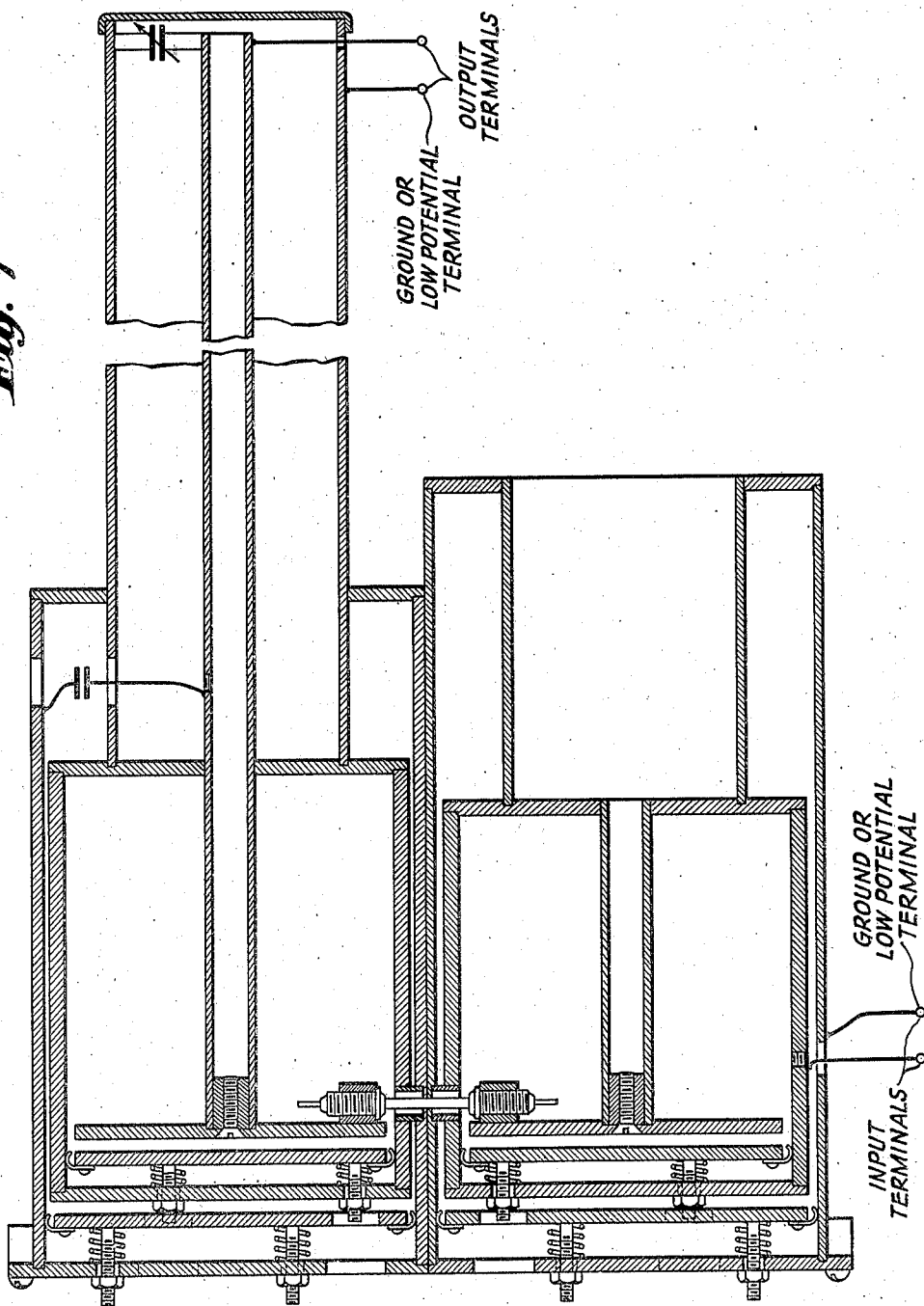
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Fig. 7



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ELECTRICAL WAVE FILTER

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Fig. 10

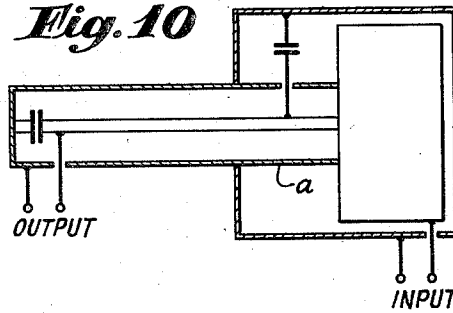


Fig. 11

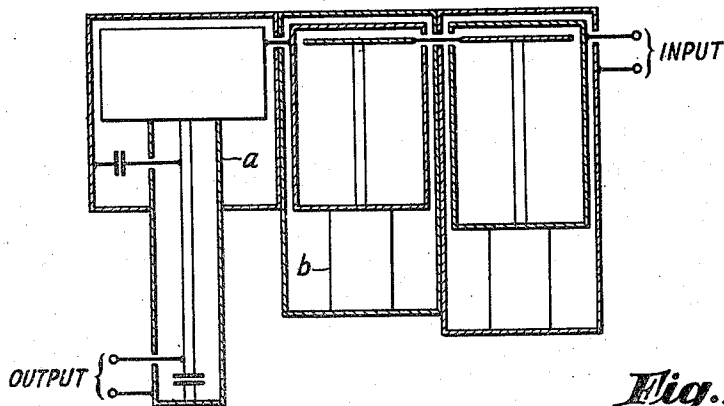


Fig. 12

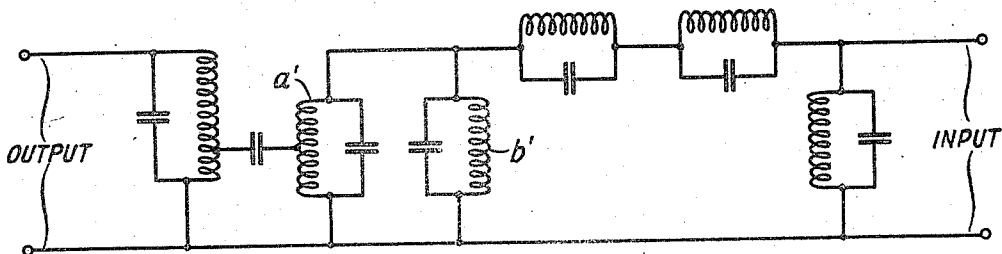
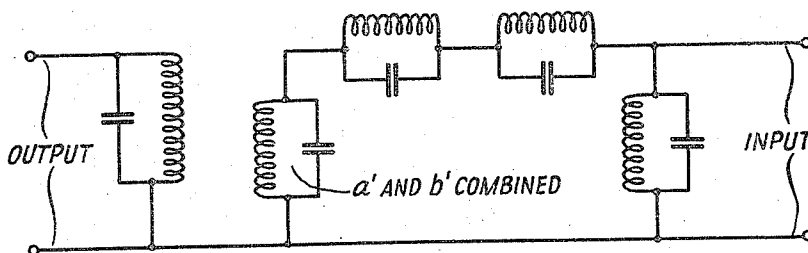


Fig. 13



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UNITED STATES PATENT OFFICE

2,220,922

ELECTRICAL WAVE FILTER

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Application March 17, 1938, Serial No. 196,362

18 Claims. (Cl. 178-44)

This invention relates to band-pass electrical wave filters employing concentric line resonators as tuned circuits, and particularly to band-pass filters suitable for passing wide band television signals at ultra high frequencies.

In the radio field it is often desirable to operate a transmitter and receiver in close proximity, and with as small a frequency separation as possible without introducing transmitter interference in the receiving system. To do this requires excellent selectivity preceding the first receiving tube to prevent cross modulation products from appearing in the receiver output. In the case of wide band systems at ultra high frequencies it is difficult with conventional methods to obtain the required flat band-pass along with sharply rising attenuation on each side of the band-pass.

The present invention provides a more effective way to accomplish this desired result and has for one of its objects to provide a band-pass filter having uniformly low attenuation over a desired band of frequencies, sharply rising attenuation at the edges of the pass-band, and high attenuation above and below the pass-band. Another object is to provide a very effective shielded filter for use at ultra high frequencies, the filter to be such that trial and error are essentially eliminated in the final adjustments.

The design of band-pass filters employing coiled inductance is well known to the art and it is also known that the losses in the filter elements impose restrictions upon the attenuation versus frequency characteristic that may be obtained with any given network. For this reason, a distinct advantage is obtained by using, in accordance with the invention, tuned circuits in the form of concentric line resonators as filter elements having very low loss, along with capacitances having comparable losses. In the frequency range from 100 megacycles to 200 megacycles, concentric line resonators can easily be built to have a Q (ratio of reactance to resistance) of 1000 to 10,000, depending upon the diameters of conductors used. Furthermore, concentric line resonators may be totally enclosed, giving essentially perfect shielding from outside fields, which is a necessary requirement when the filter is located near a transmitter.

As is known, a concentric line resonator comprises an outer conductor and a coaxial inner conductor, both conductors being coupled in such fashion that the inductance of the conductors together with the capacitance between the same combine to form a resonant circuit whose resonant frequency is determined to a large extent

by the dimensions of the conductors. One such concentric resonant line consists of two concentric conductors conductively coupled together at one of their adjacent ends and capacitively coupled together at their other ends. Examples of such concentric line resonators are described in British Patent No. 460,118, dated January 21, 1937; United States Patent No. 2,192,805, granted December 21, 1937; United States Reissue Patent No. 20,139, granted December 1, 1936; and in the article by Clarence W. Hansell entitled "Resonant lines for frequency control," published in "Electrical Engineering," August, 1935, pages 852-857, to which reference is herein made for a more complete description of the general operation of concentric line resonators.

In brief, the present invention relates to the class of filters generally described in my copending application Serial No. 191,424, filed February 19, 1938, and concerns improvements thereover.

Other objects, features and their advantages will appear from a reading of the following detailed description of the invention, which is accompanied by drawings wherein:

Fig. 1 illustrates, by way of example only, a band-pass filter constructed in accordance with the principles of the present invention;

Fig. 1a shows the circuit which is electrically equivalent to the filter of Fig. 1;

Fig. 2 graphically illustrates the attenuation versus frequency characteristic of the filter of Fig. 1;

Fig. 3 shows a filter section, constructed of concentric resonators, having unequal terminal impedances, one terminal of which can be made to have the same characteristic impedance as the filter of Fig. 1;

Fig. 4 shows the circuit which is electrically equivalent to the filter of Fig. 3;

Fig. 5 shows a filter arrangement in accordance with the invention, of the mid-series, m -derived type;

Fig. 6 shows the circuit which is electrically equivalent to the filter of Fig. 5;

Fig. 7 illustrates another form of filter of the invention, which combines some of the features of Figs. 1 and 3;

Figs. 8 and 9 illustrate filter circuits in accordance with the invention, for obtaining a desired selectivity between radio frequency vacuum tube stages;

Fig. 10 shows a filter circuit in accordance with the invention which is equivalent to that of Fig. 3;

Fig. 11 shows a cascade filter arrangement comprising the combination of Figs. 1 and 10;

Fig. 12 shows the circuit which is electrically equivalent of the filter arrangement of Fig. 11; 5 and

Fig. 13 is a circuit similar to that of Fig. 12 wherein the two inductances a' and b' are combined to form a single inductance.

Referring to Fig. 1, there is shown a band-pass 10 filter composed of two similar sections or halves which are electrically coupled together, the corresponding elements of which have the same reference numerals, except that the reference numerals of one section or half have a prime designation. Each section or half is composed of two 15 concentric line resonators, one contained within the other. Because the two halves of the filter of Fig. 1 are similar in their mechanical construction, it is deemed necessary to describe only one of these, let us say the lower half of the filter as it is shown in the drawings.

The outer concentric line resonator of the lower half of the filter of Fig. 1 comprises an 20 outer metallic cylindrical conductor 1 and an inner conductor consisting of two metallic cylindrical, coaxial, conductors 3, 2 of different diameters. Conductors 2 and 3 are hollow and are connected together at their adjacent ends by metallic end plate 9. The other end of conductor 2 25 is closed by metallic end plate 5, while the other end of conductor 3 is directly connected to one end of cylinder 1 by means of metallic end plate 10. The other end of cylinder 1 is closed by an end plate 11, in turn connected to 30 and supporting, by means of bolts 24 and nuts 12, a circular plate 4, the latter forming a capacitance with plate 5 from which it is spaced. Plate 4 is fitted around its periphery with spring 35 contacts 14 to make a positive low resistance connection to conductor 1. Movement of plate 4 with a consequent adjustment of the capacity between plates 4 and 5 and variation of the resonant frequency of the resonator, is achieved by 40 turning the adjusting nuts 12. Springs 13 serve to force plate 4 toward plate 5 upon unscrewing nuts 12. Cylinders 1, 2, 3 and end plates 4, 5, 9 and 10 are made of a highly electrically conductive material, such as copper, or have their surfaces coated with such a material.

In effect, the outer line resonator 1, 10, 3, 9, 2, 5, 4 is a tuned circuit; the small diameter section 3 may be considered to form with the outer conductor 1 an effective inductance, and the larger diameter section 2 may be considered 55 to form with the outer conductor 1 an effective capacitance. The entire effective capacitance of the outer concentric resonator is formed by the capacitance between the cylindrical conductors 1 and 2, and by the capacitance between end plates 4 and 5. Such an arrangement is generally described in United States Patent No. 2,124,029, granted to James W. Conklin et al. July 19, 1938, to which reference is made for a complete technical description of this particular 65 type of two-diameter inner conductor concentric line resonator.

The inner concentric line resonator of the lower half of the filter of Fig. 1 is contained within cylinder 2 and consists of an inner cylindrical coaxial rod 8 which is directly connected at one end to the inner surface of cylinder 2 by end plate 9, and capacitively connected at its other end to the cylinder 2 by means of circular plates 7 and 6. Plate 7 is directly connected to 75 rod 8, while plate 6 is supported on plate 5 and

suitably spaced away from plate 7. Plate 6 is provided with a spring contact 17 at its periphery to make a low resistance connection with cylinder 2, and is adjustable in position relative to plate 7 by means of nuts 15 and bolts 25. 5 Springs 16 serve the same purpose for the inner resonator as do springs 13 for the outer resonator. All plates and cylinders are made of material having high electrical conductivity.

In effect, the inner line resonator 2, 9, 8, 7, 10 6 is a tuned circuit. The conductor 8 forms with the cylinder 2 an effective inductance, while the spacing between plates 6 and 7 forms an effective capacitance. There is also a small capacitance between the edge of plate 7 and cylinder 2. 15

The two halves of the filter of Fig. 1 are connected together by means of a connector 19 supported at each end by pin jacks 18 and 18'. At this location, a small amount of stray unwanted 20 coupling appears between the two halves of the filter, and for this reason there are provided the metallic sleeves 20 and 20' to prevent connector 19 from being capacitively coupled to ground. Such a capacitive coupling to ground would 25 be somewhat detrimental to the normal operation of the filter. The addition of the sleeves 20 and 20' materially reduces the capacitance between conductor 19 and ground and adds a small capacitive coupling between conductors 2 30 and 2'. In most cases, this small coupling does not materially affect the proper operation of the filter. The term "ground" as herein employed refers to any of the external conductors 1, 10, 35 11, 4, 1', 10', 11', 4' which may be at zero or a relatively fixed alternating current potential.

The input terminals to the filter of Fig. 1 are 21 and 22, while the output terminals are 21' and 22'. Apertures are provided in the outer cylinders 1 and 1' near terminals 21 and 21' to 40 enable connection from external circuits to conductors 2 and 2', respectively, at terminal points 22 and 22'. It should be understood, of course, that the input and output terminals may be used interchangeably, and terminals 22 and 22' 45 may be located at any point along the length of cylinder 2 and 2' respectively.

A better understanding of the filter of Fig. 1 may be had by referring to the electrically equivalent circuit shown in Fig. 1a, which, it will be 50 evident, is the familiar mid-shunt section of an m -derived type of band-pass filter. The theory underlying this type of filter section is well known and is described by Shea in his book entitled "Transmission Networks and Wave Filters," 55 published in 1929 by D. Van Nostrand Company, Inc., New York. The constants of the filter of the invention are designed to conform with well known practices, as set forth for example by Shea on page 315 of the above mentioned book. 60

In Fig. 1a, the elements shown to the left of the vertical dot and dash line are contained within the cylindrical conductor 1, of Fig. 1, and the elements to the right of the dot and dash line are contained within the cylindrical conductor 1' of Fig. 1. The shunt input inductance 2L2 is formed by the cylindrical conductor 3 located within and coaxial with respect to conductor 1. The shunt input capacitance $C_{2/2}$ is 65 formed by the capacitance between the cylindrical conductors 1 and 2, and the circular end plates 4 and 5. The series elements L_1 and C_1 are contained entirely within conductor 2. The inductance L_1 is formed by the cylindrical conductor 8 located within and coaxial with respect 75

to conductor 2. The capacitance C_1 is formed by the capacitance between circular plates 6 and 7, and the small capacitance between the edge of plate 7 and conductor 2.

The elements of Fig. 1a shown to the right of the vertical dot and dash line, are contained within the cylindrical conductor 1' of Fig. 1, in the same manner as the correspondingly located elements to the left of the vertical line are contained within cylinder 1. The values of L_3 and C_3 of Fig. 1a differ from the values of L_1 and C_1 , respectively, as required by a particular design of the filter. It should be noted in this connection that elements 8' and 2' of Fig. 1 are slightly longer than the corresponding elements 8 and 2.

It should be observed that the construction of the filter of the invention is such that the elements L_1 , C_1 and L_3 , C_3 are completely enclosed within their respective conductors 2 and 2', and consequently are completely isolated, both capacitively and inductively, from any other element in the filter or from ground. In similar manner, each element of the filter has no undesired coupling to any other element of the filter, except as mentioned above.

Fig. 2 graphically illustrates the measured attenuation versus frequency curve of the filter of Fig. 1. In Fig. 2, the ordinate represents attenuation in decibels, while the abscissa represents frequency in megacycles. An inspection of this curve will show that the band-pass filter of Fig. 1 has substantially zero attenuation over the band of frequencies from about 127 megacycles to 133 megacycles; sharply rising attenuation at the edges of the pass band, and high attenuation above and below the pass band. In the filter of Fig. 1, for which Fig. 2 is the curve, f_m is 139 mc.; f_1 is 126.0 mc.; f_2 is 134.13 mc.; $f_{1\infty}$ is 121.1 mc.; $f_{2\infty}$ is 139.4 mc.; R is 100 ohms, and m is 0.895, where f_1 and f_2 are the lower and upper nominal cut off frequencies, $f_{1\infty}$ and $f_{2\infty}$ are the lower and upper frequencies at which maximum attenuation occurs, f_m is equal to

$$\sqrt{f_1 f_2}$$

and

$$\sqrt{f_{1\infty} f_{2\infty}},$$

R is the characteristic impedance at mid-band, and m is equal to

$$\sqrt{1 - \frac{\left(\frac{f_2}{f_m} - \frac{f_m}{f_2}\right)^2}{\left(\frac{f_{2\infty}}{f_m} - \frac{f_m}{f_{2\infty}}\right)^2}}$$

One advantage of the filter of Fig. 1, it will be appreciated, is that it lends itself to easy insertion in a coaxial transmission line, providing the line and filter characteristic impedances are properly matched. In such a case the outer conductor of the input transmission line would connect to conductor 1 at point 21 and the inner conductor of the transmission line would connect to conductor 2 at point 22. Similarly, the output transmission line would connect to points 21' and 22'. Of course, the filter can be used in other arrangements, for example, between any two resistive impedances, of any sort whatever, having the correct value.

One or more filter sections of the present invention may be cascaded to give increased attenuation outside of the pass-band and a sharper rise of attenuation at the edges of the pass-band. Also, any other type of filter section having the same image impedance may be cascaded with the

filter of the present invention to give any desired characteristic that it is possible to obtain. For example, the filter section shown in Fig. 3, constructed of concentric line resonators 26 and 27, may be built to have unequal terminal impedances one of which, let us say 26, will be similar to and will match that of the filter shown in Fig. 1. The other, or output terminal impedance of the section of Fig. 3, let us say 27, may be made higher or lower than its input terminal impedance. In this way, the filter sections of Figs. 1 and 3 may be cascaded. It should be noted that concentric line resonator 26 is of the two-diameter inner conductor type, while concentric line resonator 27 has an inner conductor of only one diameter. Both resonators are capacitively coupled together by means of a condenser 28 located, at least partly, within the outer conductor of resonator 27. The outer conductors of both line resonators are maintained at zero or a fixed alternating current potential by means of ground connections 29 and 30. Input terminals connect, by way of example only, to the outer conductor of resonator 26 and the high potential end of the inner conductor of this same resonator. Output terminals are shown connected to the outer conductor of resonator 27 and to the high potential end of the inner conductor of the same resonator. The section shown (Fig. 3) provides a step-up of impedance which might be used in conjunction with the filter of Fig. 1 to provide a network to give a desired degree of selectivity between a coaxial transmission line and the grid electrode of a thermionic amplifier or detector vacuum tube.

Fig. 4 shows the circuit which is electrically equivalent to the filter of Fig. 3. The elements of Fig. 4 shown to the left of the vertical dash line comprise the concentric line resonator 26, while the elements to the right of the vertical dash line, except for the coupling capacitor 28, comprise the concentric line resonator 27. The theory underlying the type of filter shown in Fig. 4 is well known and is described in the book by Shea, supra.

Fig. 5 illustrates, schematically, a filter embodiment of the invention, making use of the mid-series section of the m -derived filter. The circuit which is electrically equivalent to the filter of Fig. 5 is shown in Fig. 6. A better understanding of Fig. 5 may be had by referring to the conventional electrical equivalent circuit of Fig. 6. The same symbols have been used in both of these figures to designate equivalent elements.

In effect, Fig. 5 consists of five tuned circuits in the form of five concentric line resonators, all contained within the hollow metallic container 31. The shunt line resonator (corresponding to L_2 , C_2 of Fig. 6) comprises the two-diameter inner conductor 32, 33 and the outer conductor 31. Conductor 33 is hollow and by virtue of its close spacing to conductor 31 forms an effective capacitance therewith. The interior of hollow conductor 33 is separated into two chambers A and B by means of a metallic partition wall 34. In each of these two chambers are two other concentric line resonators, one resonator of which comprises the inner conductor 35, 36, of two diameters, and an outer conductor consisting of the inner surface of hollow conductor 33 in that particular chamber, and the other resonator of which is located within hollow portion 36 and comprises an inner conductor 37, and an outer conductor which is the inner surface of conductor 36. It should be noted that the arrangement of two concentric line resonators within

each of chambers A and B is substantially similar in construction to one-half of the filter shown in Fig. 1. The adjustments of the resonant frequencies of the individual line resonators may be made as shown and described in Fig. 1, or in any other suitable fashion.

An inspection of the filter of Fig. 5 will show that each concentric line resonator is inherently perfectly shielded from all the other line resonators, so that there is no unwanted coupling between elements of the filter, with the exception of a slight stray capacitive coupling at the location of the input and output terminal leads where they pass through the three conducting shells 36, 33 and 31, as shown.

Fig. 7 shows a band-pass filter in accordance with the invention, wherein certain features of the filters of Figs. 1 and 3 are combined.

If it is desired to supply selectivity between two radio frequency vacuum tubes, use may be made of two sections similar to that of Fig. 3, one preceding and one following the filter of Fig. 1 to allow a step-down from the plate circuit of one vacuum tube and a step-up to the following grid circuit of the other vacuum tube, as shown in Fig. 8. The circuit of Fig. 8 can be simplified to that shown in Fig. 9 by combining adjacent parallel resonators into a single resonator having proper constants determined by methods well known to the art.

In Fig. 10 is shown a filter section equivalent to that of Fig. 3. This equivalence is described in my copending application, Serial No. 191,424, supra. Fig. 11 shows the filter of Fig. 1 cascaded with that of Fig. 10. Fig. 12 shows the equivalent electrical circuit of Fig. 11, and Fig. 13 shows the equivalent electrical circuit of Fig. 12, wherein the two inductances a' , b' are combined to form a single inductance as shown. The circuit (Fig. 13) is also the electrical equivalent of the arrangement of Fig. 7 in which the output shunt elements of the m -derived section are combined with the input shunt elements of the filter of Fig. 10 to form a single LC circuit. A combination of the sort described above gives, in effect, a filter having certain desired selectivity characteristics as well as providing a means of transforming from one impedance value to another. Such impedance transfers are desirable to couple a low impedance transmission line to the grid of a tube while at the same time giving the selectivity provided by the particular filter combination used.

What is claimed is:

1. A band-pass electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, a second resonant circuit located within said metallic enlargement and coupled thereto; a similar arrangement of third and fourth resonant circuits, and means coupling together said two arrangements.

2. A band-pass electrical wave filter comprising a resonant circuit composed of a section of coaxial transmission line employing a metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, another resonant circuit composed of a section of coaxial transmission line of different dimensions than the section of line of said first resonant circuit, and means comprising still a third resonant circuit composed of a section of coaxial transmis-

sion line located within said metallic enlargement and coupling said first and second resonant circuits together.

3. A band-pass electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, a second resonant circuit located within said metallic enlargement and coupled thereto; a similar arrangement of third and fourth resonant circuits, and means coupling together said two arrangements, said resonant circuits being so constructed and coupled together as to provide a filter having uniformly low attenuation over a desired band of frequencies, sharply rising attenuation at the edges of the pass-band, and high attenuation above and below the pass-band.

4. A band-pass electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, a second resonant circuit located within said metallic enlargement and comprising an inner conductor and an outer conductor, the latter of which is the inner surface of said enlargement, a similar arrangement of third and fourth resonant circuits, and a conductive connection between the inner conductors of said second and fourth resonant circuits.

5. A band-pass electrical wave filter of the m -derived type comprising shunt and series resonant circuits, said shunt resonant circuit being composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, said series resonant circuit being located within said metallic enlargement and comprising an inner conductor which cooperates with the inner surface of said enlargement to form a tuned circuit in the form of a section of coaxial transmission line.

6. A band-pass electrical wave filter comprising a shunt and a plurality of series resonant circuits, said shunt resonant circuit being composed of a section of coaxial transmission line having a metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, a partition dividing said metallic enlargement into two chambers, and a series resonant circuit located in each chamber, each of said series resonant circuits comprising an inner conductor which cooperates with the inner surface of its associated chamber to form a tuned circuit in the form of a section of coaxial transmission line.

7. A band-pass electrical wave filter comprising a shunt and a plurality of series resonant circuits, said shunt resonant circuit being composed of a section of coaxial transmission line having a metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, a partition dividing said metallic enlargement into two chambers, and two series resonant circuits located in each chamber, one of said series tuned circuits in each chamber comprising an inner conductor which cooperates with the inner surface of its associated chamber to form a tuned circuit in the form of a section of coaxial transmission line, said last inner conductor also having a hollow metallic enlargement at one end to form a lumped tuning capacitance, the other series resonant circuit in each chamber being located within the enlargement of the inner con-

ductor of the first series resonant circuit in said chamber.

8. The combination with an input circuit and an output circuit, of a band-pass filter connected between said output and input circuits, said filter providing a step-down in impedance from said output circuit and a step-up in impedance to said input circuit, said filter including at least two cascaded filter sections each of which is composed of a resonant circuit comprising a portion of a coaxial transmission line having a metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, and another resonant circuit also comprising a portion of a coaxial transmission line, and means for capacitively coupling the inner conductors of both resonant circuits of each filter section together, there being a connection provided for coupling together said metallic enlargements of both filter sections.

9. The combination with an input circuit and an output circuit, of a band-pass filter connected between said output and input circuits, said filter providing a step-down in impedance from said output circuit and a step-up in impedance to said input circuit, said filter including at least two cascaded filter sections each of which is composed of a resonant circuit comprising a portion of a coaxial transmission line having a metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, and another resonant circuit also comprising a portion of a coaxial transmission line, and means for coupling the inner conductors of both resonant circuits of each filter section together, there being a connection provided for coupling together said metallic enlargements of both filter sections.

10. A band-pass filter in accordance with claim 1, characterized in this that the inner resonant circuit of either section of transmission line is a coiled inductance having suitable tuning capacitance.

11. A band-pass electrical wave filter comprising a resonant circuit composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped tuning capacitance, and a second resonant circuit located completely within said metallic enlargement and coupled thereto.

12. A filter comprising first and second tuned circuits in the form of concentric line resonators each having an inner and an outer conductor, the inner conductor of said first tuned circuit having a hollow metallic enlargement at one end thereof to form a lumped capacitance, said second tuned circuit being located completely within said metallic enlargement, whereby the inner surface of said metallic enlargement forms the outer conductor of said second tuned circuit.

13. An electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped capacitance, and a second resonant circuit located completely within said metallic enlargement and composed of a section of coaxial transmission line having an inner con-

ductor of uniform longitudinal dimensions, a capacitive connection between said hollow metallic enlargement of said first resonant circuit and said inner conductor of uniform longitudinal dimensions of said second resonant circuit, said hollow enlargement and its associated outer conductor comprising one set of terminals for said filter, and said inner conductor of uniform dimensions and its associated outer conductor comprising another set of terminals for said filter.

14. An electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow metallic enlargement at one end of the inner conductor to form a lumped capacitance, and a second resonant circuit composed of a section of coaxial transmission line having an inner conductor of uniform longitudinal dimensions, a connection between said hollow metallic enlargement of said first resonant circuit and said inner conductor of uniform longitudinal dimensions of said second resonant circuit, and a set of third and fourth resonant circuits similarly constructed to said first and second resonant circuits, and means for coupling together the hollow metallic enlargements of both sets of resonant circuits.

15. A filter in accordance with claim 14, characterized in this that said means is composed of additional resonant circuits in the form of sections of coaxial transmission line.

16. An electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line whose inner conductor has two hollow sections of different diameters, and a second resonant circuit composed of a section of coaxial transmission line located completely within the smaller diameter section of the inner conductor of said first circuit, whereby the inner surface of said smaller diameter section forms the outer conductor of said second resonant circuit, and means for capacitively coupling said resonant circuits together.

17. An electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow inner conductor, a second resonant circuit composed of a section of coaxial transmission line, and means coupling said two resonant circuits together comprising a third resonant circuit, said third resonant circuit being located completely within the hollow inner conductor of said first resonant circuit.

18. An electrical wave filter comprising a first resonant circuit composed of a section of coaxial transmission line having a hollow inner conductor, a second resonant circuit composed of a section of coaxial transmission line, and means coupling said two resonant circuits together comprising a third resonant circuit, said third resonant circuit being located completely within the hollow inner conductor of said first resonant circuit and composed of coaxial metallic surfaces, the outer surface of which is the inner surface of the inner conductor of said first resonant circuit.

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