Oct. 10, 1950 — W. A. MONTGOMERY — 2,524,821

WIDE FREQUENCY BAND AMPLIFIER

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FIG. 1.

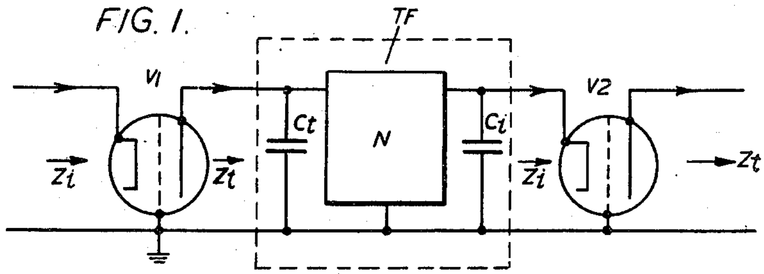


FIG. 2.

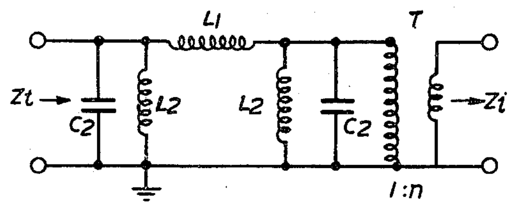
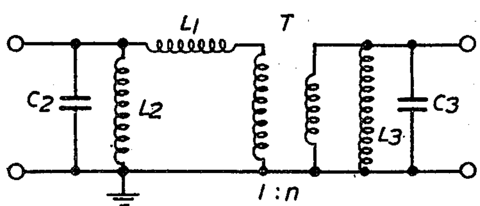
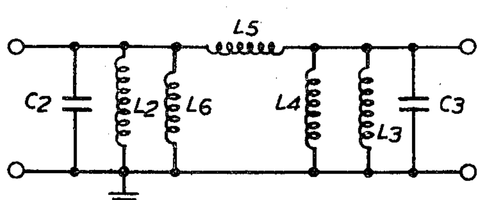


FIG. 3.



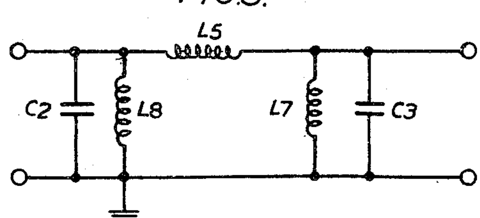
$$L_3 = n^2 L_2$$
$$C_3 = C_2/n_2$$

FIG. 4.



$$L_4 = n^2 L_1/(1-n)$$
$$L_5 = nL_1$$
$$L_6 = nL_1/(n-1)$$

FIG. 5.



$$L_5 = nL_1$$
$$L_7 = n^2 L_1 L_2/[L_1 + L_2(1-n)]$$
$$L_8 = L_1 L_2/[L_1 + L_2(\tfrac{n-1}{n})]$$
$$C_3 = C_2/n^2$$

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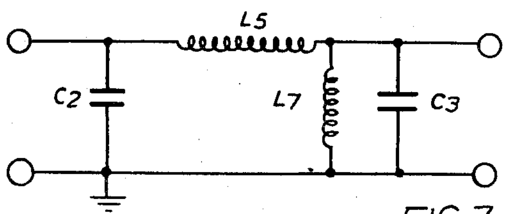
FIG. 6.



$$L_2 = nL_1/(1-n)$$
$$L_5 = nL_1$$
$$L_7 = nL_1/(1-n^2)$$
$$C_3 = C_2/n^2$$

FIG. 7.

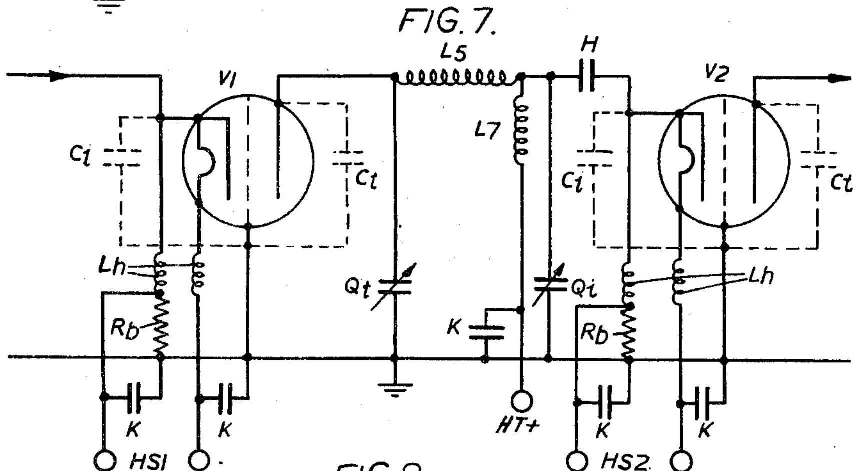


FIG. 8.

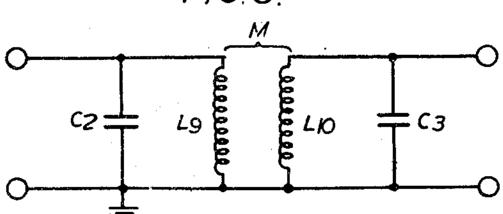


FIG. 9.

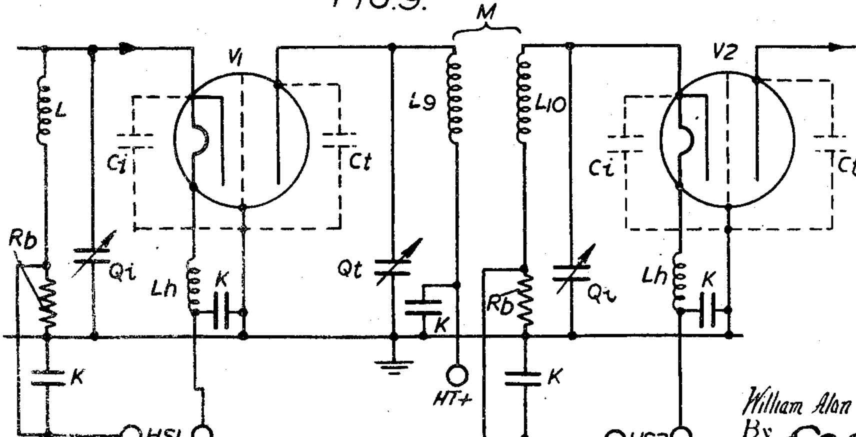


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FIG. 10.

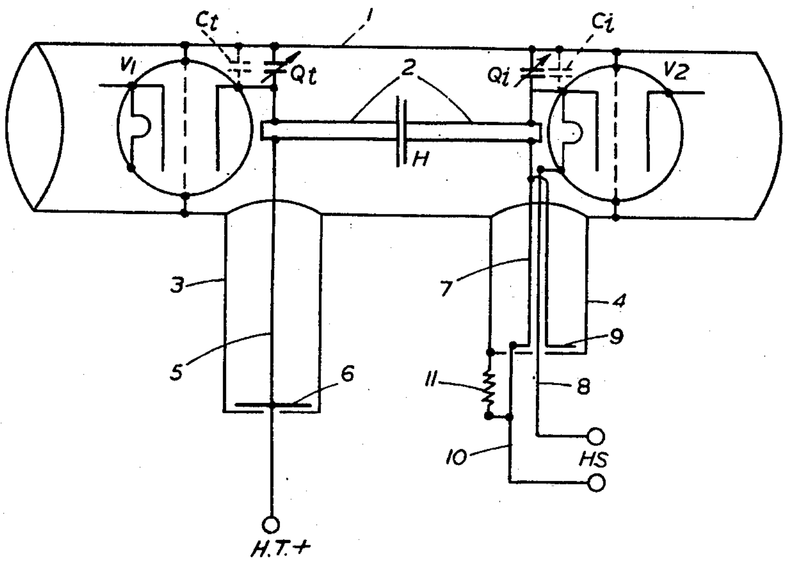
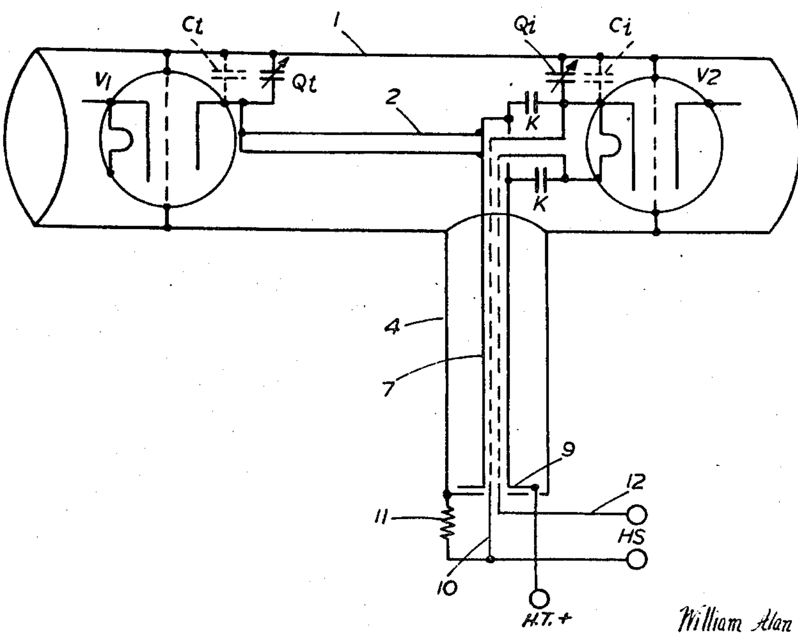


FIG. 11.



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UNITED STATES PATENT OFFICE

2,524,821

WIDE FREQUENCY BAND AMPLIFIER

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Application March 5, 1945, Serial No. 581,098
In Great Britain December 28, 1943

Section 1, Public Law 690, August 8, 1946
Patent expires December 28, 1963

6 Claims. (Cl. 179—171)

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The present invention relates to multi-stage amplifiers employing thermionic valves of the grounded-grid type and is concerned with the interstage coupling arrangements for such amplifiers, particularly those designed for use at ultra-high frequencies.

The valves are of the kind intended to be operated with the control grid connected to earth, or at least maintained at earth potential for the signal waves. The input signal voltages are therefore applied to the cathode, and the output voltages are taken between the anode and control grid. The valve operated in this way has a very low input impedance, and the reactances associated with the output circuits of the valves may have a controlling influence on the coupling arrangements of two successive stages. Furthermore, since the input impedance of the valve is low, the coupling arrangements must fulfil certain definite conditions if maximum gain over the transmitted band is to be obtained, which conditions are quite different from those which apply when the valves are operated in the usual way.

The principal object of the present invention is to provide an efficient coupling network for two stages of a grounded-grid valve amplifier intended to pass a specified band of frequencies. While the frequencies of special interest to the invention are in the ultra-high-frequency range, the same principles are applicable in other ranges.

According to the invention there is provided an electric wave amplifier comprising two thermionic valves having their control grids connected to ground, and a network connecting the anode of the first of the said valves to the cathode of the second valve, the said network being so designed that when combined with the inter-electrode capacities of the valves it constitutes a transforming filter adapted to pass a frequency band of specified width, the output image admittance of the said filter at the mid-band frequency being equal to the conductance component of the cathode-control grid admittance of the said second valve at that frequency, when the anode of that valve is connected to a network similar to the said network or to an equivalent load.

In a rather more specific form, the invention also provides an electric wave amplifier comprising two thermionic valves having their control grids connected to earth, a system of hollow metal tubes enclosing the said valves and having central conductors connected in such a manner as to form with the inter-electrode capacities of the said valves a transforming filter for coupling the anode of one valve to the cathode of the other

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valve, the said filter being adapted to pass a band of frequencies of specified width, and having an output image admittance at the mid-band frequency equal to the conductance component of the cathode-control grid admittance at that frequency of the said other valve when the anode of that valve is loaded by a similar transforming filter, or by an equivalent load.

The invention will be described with reference to the accompanying drawings in which:

Fig. 1 shows a schematic circuit diagram showing two grounded grid valves coupled by an arrangement according to the invention;

Figs. 2 to 6 show circuit diagrams of filters to show how a transforming filter according to the invention may be evolved;

Fig. 7 shows a schematic circuit diagram of two stages of an amplifier employing a filter according to Fig. 6;

Fig. 8 shows an alternative configuration for the transforming filter;

Fig. 9 shows a schematic circuit diagram of two stages of an amplifier employing a filter according to Fig. 8; and

Fig. 10 shows an embodiment of an amplifier employing a filter having the configuration of Fig. 5.

Figure 11 shows another embodiment employing a filter having the configuration of Figure 6.

The invention is not restricted to amplifiers employing simple grounded-grid triodes only. There may be any number of electrodes, and the valves may be of special types, such as beam tetrodes or aligned-grid tetrodes, provided always that the control grid is earthed. However, triode valves having three parallel plane electrodes specially designed for ultra-high frequencies are of particular interest in connection with the present invention. Such valves are described, for example, in the specification of U. S. Patent No. 2,419,544.

In coupling valves together, the reactances associated with the input and output circuits of the valve, and with the connection leads, must be taken into account and may be controlling factors, and it has been found that these reactances can be utilised to form the elements or parts of the elements of a band-pass coupling filter designed to pass with a minimum of distortion a certain band of frequencies. As has already been mentioned, the input impedance of a grounded grid valve is rather low, and therefore in order to obtain a coupling which operates with maximum efficiency, the coupling filter should include the equivalent of a step-down transformer. In other words, an impedance transforming filter is required.

The reasons for the particular choice of the characteristics of the coupling filter according to the invention will now be explained.

Let μ be the amplification factor of the type of grounded-grid valve chosen for use. Let R be its internal impedance, that is, $R=(E+\mu e)/i$, where E and e are the instantaneous values of the A. C. components of the anode-cathode and control grid-cathode voltages, and i is the corresponding instantaneous value of the A. C. component of the anode current. It can be shown by simple circuit theory that the input impedance Z_i measured between the cathode and control grid is given by:

$$Z_i=(R+Z_t)/(\mu+1) \quad (1)$$

where Z_t is the external load impedance connected between the anode and control grid of the valve. This is on the assumption that there is no grid current, that the anode-cathode capacity of the valve is negligible, and that the cathode-control grid and anode-control grid capacities C_i and C_t are considered as parts of the external circuits connected to the valve.

Fig. 1 shows in block schematic form a circuit according to the invention. There are shown two similar grounded grid valves V_1 and V_2 coupled by a network N of reactive elements which together with the valve capacities C_t and C_i forms a transforming filter TF. This filter is terminated on its output side by the impedance Z_i, and Z_t is the impedance measured at its input terminals when so terminated.

Assuming that the anode-cathode capacity of the valve is negligible, so that no direct feedback occurs between the anode and cathode circuits, it is easy to show that the power gain introduced by the valve at any frequency is determined by the radio G of the real part of Z_t to the real part of Z_i. This can be seen because the current flowing in at the cathode (into Z_i) must be the same as the current flowing out at the anode (into Z_t), it being assumed that there is no grid current.

It will be understood from what has already been explained, that according to the invention, the capacities C_t and C_i are treated as though they formed part of the coupling filter TF. These capacities will be taken to include any additional stray capacities introduced by leads, and the like, which will, of course, be reduced to a minimum. They will therefore be neglected for the present when considering the action of the valves, which will thus be assumed not to have any capacities associated with them.

The design of the filter TF will be treated first of all in terms of the mid-band angular frequency ω_0 which is equal to $\sqrt{\omega_1 \cdot \omega_2}$, where ω_1 and ω_2 are the two cut-off angular frequencies.

From Equation 1 it can be seen that Z_i is real if Z_t is real, and vice-versa. Let it be assumed that Z_i is real and equal to R_i. The coupling filter TF will be designed according to the invention so that its output image impedance at ω_0 is R_i. Then its input image impedance will be R_i/n^2 where n is less than 1 and is the transformation ratio of the equivalent step-down transformer effectively contained in the filter. Thus

$$Z_t=R_i/n^2=R_t$$

and is real, so that the condition of Equation 1 is satisfied. Thus substituting in Equation 1 we have

$$n^2R_t=(R+R_t)/(\mu+1) \quad (2)$$

and therefore

$$G=R_t/R_i=1/n^2=R_t(\mu+1)/(R+R_t) \quad (3)$$

Thus G increases as R_t increases, and the maximum theoretical value of G is therefore $\mu+1$, but only much smaller values are usually possible for reasons which will appear later.

In order to fulfill these requirements it will be necessary to provide an anode load equal to R_t at the mid-band angular frequency ω_0 for the last amplifying valve of the series, then the anode load of all the other valves will be R_t as desired.

The properties of various types of band-pass filters are summarised in Fig. 168A, B and C of the book "Transmission Networks and Wave Filters" by T. E. Shea. In view of the desirability to include the capacities C_t and C_i as parts of the filter, it is necessary to choose a configuration which can have shunt capacities at the ends. Also, in order to obtain the maximum gain, R_t should be as large as possible, and this requires that the input shunt capacity of the filter should be as small as possible. The smallest possible value of this capacity is C_t, the unavoidable anode-control grid capacity of the valve. By reference to Fig. 168A, B and C of the work mentioned above, several of the simpler configurations are suitable, and of these Nos. IV_k and III_3 give the largest band-width $\omega_2-\omega_1$ for given values of C_t and R_t. Practically all the others give a smaller bandwidth and are therefore less suitable. Of the two selected, configuration III_3 is the simpler and is the preferred configuration according to this invention. However, other forms could be used, if desired.

The configuration III_3 is shown in Fig. 2, to which has been added an ideal transformer T to introduce the ratio n, in which the components indicated have the following values:

$$L_1=2R_t/(\omega_1+\omega_2) \quad (4)$$

$$L_2=R_t(\omega_2-\omega_1)/\omega_1^2 \quad (5)$$

$$C_2=1/(\omega_2-\omega_1)R_t \quad (6)$$

Since the transformer has been introduced on the output side of the filter, the input characteristic impedance of the filter is R_t, and it will be properly terminated by the impedance R_i connected on the other side of the transformer. It will be understood from what has already been explained, that R_i is provided by the input circuit of the valve V_2, from which circuit the capacity C_i has been removed and considered as part of the filter. Thus the admittance $1/R_i$ is the same as the conductance component of the admittance of the input circuit of the valve, which admittance could, of course, only be measured with the capacity C_i present. Likewise, although $1/R_t$ is the input image admittance of the filter, it would most probably be measured as the conductance component of the admittance looking into the input side of the network N (Fig. 1), but the capacity C_t could be included by making the measurement with the valve V_1 in position, but with the heater switched off.

The transformer T may be incorporated into the network by the series of well known transformations shown in Figs. 3, 4 and 5. In Fig. 3 it has been moved to the left-hand side of L_2 and C_2, so that these elements are changed respectively to $L_3=n^2L_2$, and $C_3=C_2/n^2$. The transformer combined with L_1 is equivalent to the three inductances L_4, L_5 and L_6 shown in Fig. 4, the values of which are $L_4=n^2L_1/(1-n)$, $L_5=nL_1$, and $L_6=nL_1/(n-1)$. It will be noted that L_6 is negative, since n is less than 1.

By combining the inductances L_3, L_4 and L_2, L_6, the filter of Fig. 5 is obtained, in which:

$$\left.\begin{aligned} L_5&=nL_1\\ L_7&=n^2L_1L_2/[L_1+L_2(1-n)]\\ L_8&=nL_1L_2/[n(L_1+L_2)-L^2]\end{aligned}\right\} \qquad (7)$$

If L_8 is to be physically realisable it must be positive, and therefore L_2 must not exceed $nL_1/(1-n)$.

The prefered design procedure for the filter is as follows:

C_2 is first taken equal to C_t, the anode grid capacity of the valve together with the capacity of any leads attached thereto. The specified band width $\omega_2-\omega_1$ then determines R_t from Equation 6. The inductances L_1 and L_2 are then determined from Equations 4 and 5 by inserting the specified values of ω_1 and ω_2. Having determined the value of n then L_5, L_7 and L_8 are found from the Equations 7.

It will be seen from Equation 2 that n is fixed by the choice of the valve, when R_t has been determined; thus it may sometimes be found that L_8 is negative and therefore unrealisable. This means that with this particular type of filter designed in the manner explained, when the band width is specified, the mid-band angular frequency ω_0 cannot be below a certain minimum value, though it can be above. This is not a serious disadvantage in some amplifiers, because it is quite a common practice to employ frequency changing means to bring the frequency band of interest into some convenient range for amplification, and in such a case the actual value of the mid-band frequency is not of much importance, and can often be chosen to comply with the limitation of the design.

Where the choice of the mid-band frequency is free, the simplest and most economical design of the filter is obtained by choosing L_1 and L_2 so that L_8 is infinite, and is therefore omitted altogether. The filter then reduces to the form shown in Fig. 6. This requires that:

$$L_2=nL_1/(1-n) \qquad (8)$$

From Equations 4, 5 and 8, it then follows that for Fig. 6:

$$\omega_2/\omega_1=\sqrt{(1+n)/(1-n)} \qquad (9)$$

This determines ω_1 and ω_2 separately since the bandwidth $\omega_2-\omega_1$ is given, and the values of L_1 and L_2 are then found from Equations 4 and 5, and thence L_5 and L_7 from Equations 7. The filter then reduces to the simplest form shown in Fig. 6. Since $C_3=C_2/n^2$, it will usually be much larger than C_2, and will also generally be several times larger than C_i, so that C_i does not limit the design, and some extra capacity must be added to make up C_3.

The method of designing a network according to Fig. 6 will be better understood from a numerical example. The grounded grid valve chosen for use had the following constants:

Amplification factor μ	100
Anode circuit resistance R	20,000 ohms
Anode-grid capacity C_t	1.7 micro-micro-farads
Grid-cathode capacity C_i	3.4 micro-micro-farads
Band width required $(\omega_2-\omega_1)/2\mu$	40 megacycles per second.

From Equation 6, the value of R_t is found to be about 2340 ohms, by putting $C_2=C_t$ from Equation 2 $n^2=0.0945$, and thus $R_i=221.2$. From Equation 9, since $(\omega_2-\omega_1)/2\pi=40$ megacycles, it follows that

$$\left.\begin{aligned} \omega_1/2\pi &\ldots\ldots 107\\ \omega_2/2\pi &\ldots\ldots 147\\ \omega_0/2\pi &\ldots\ldots 125.4\end{aligned}\right\} \text{megacycles per second}$$

From Equation 4 $L_1=2.933$ microhenries, and thus $L_5=0.902$ microhenry and $L_7=0.094$ microhenry. Also $C_3=C_2/n^2=18.0$ micro-microfarads. Also $G=1/n^2=10.58$, corresponding to a gain of about 10.2 decibels.

It will thus be seen that C_3 is about five times C_i, so that an additional capacity of about 14.6 micro-microfarads must be connected across the output of the filter TF.

It will of course be found that the values of C_t and C_i for a number of different valves of the same type vary between certain limits. In order that the transforming filter shall give the desired performance with any valve, a small variable trimming condenser may be connected in parallel with C_2. The filter should be designed for a value of C_t equal to the maximum value for any valve, and this variable condenser is adjusted so as to bring C_t up to the maximum value for the particular valve employed. Similarly, variations in C_i will be covered by using a variable condenser to supply partly or wholly the additional capacity (about 14.6 micro-micro-farads in the example given above) required to make up C_3.

Referring again to Fig. 5, the star formation equivalent to the delta form of the three inductances L_5, L_7 and L_8 may of course be used if preferred, as it may be more convenient in some circumstances. It will, however, suffer from the same limitation as regards the minimum value of ω_0, and in the special case when Equation 8 holds both forms are identical.

The design of the filter has so far been based upon consideration of the mid-band angular frequency ω_0 at which the filter has an image impedance which is a pure resistance, and the filter can be and is terminated correctly by a pure resistance at this frequency. These conditions do not generally hold at other frequencies in the pass band when the filter is so terminated, and the gain calculated from the simple formula $G=1/n^2$ does not generally hold at other frequencies. It can, however, be shown that for the type of filter shown in Figs. 2 to 6, the gain at ω_1 and ω_2 is the same as that at ω_0, but between ω_1 and ω_0 and between ω_0 and ω_2 the gain is generally a little higher, there being two unequal maxima, one on either side of ω_0. It is however, unlikely that the maximum gain in any part of the band will be more than about 1.6 db. above the gain at ω_0.

Although the maximum gain per stage will be obtained by making $C_2=C_t$, a larger value of C_2 could be chosen if desired, whereby some freedom of design could be obtained at the expense of some reduction in the gain. This would give a lower input impedance for the filter and a larger value of n.

The gain per stage which it is possible to obtain is in effect limited by the characteristics of the valve chosen, and varies oppositely with the band width; thus wider bands imply lower gain. For valves having the same value of μ the available gain per stage is greater when R and C_t are smaller. Thus the valve should have high values of μ and low values of C_t and R.

Fig. 7 is a schematic circuit diagram to show

how the coupling filter of Fig. 6 may be applied in practice. The capacities C_i and C_t associated with the valves are shown dotted in order to indicate that they do not represent any actual circuit elements. The condensers designated K are bypass condensers of relatively large capacity so that their reactance at the operating frequency is negligible. The anode of V_1 is connected to the cathode of V_2 through the coil L_5 and a blocking condenser H. Anode potential is supplied to the anode of V_1 through the shunt coil L_7 and through L_5, the coil L_7 being effectively connected to earth through the bypass condenser K. The variable condensers Q_t and Q_i are connected in parallel with C_t and C_i and enable the desired values of the filter capacities C_2 and C_3 to be obtained in the manner described. Q_t is preferably a very small condenser having a range just sufficient to cover the maximum variation of C_t.

The cathode heaters are supplied from separate heating sources HS1 and HS2 through choke coils Lh having a very high impedance at the operating frequency in order to prevent the heating source from short circuiting the filter. These coils together with the corresponding bypass condensers K also prevent coupling between the stages through the heating sources. Cathode bias is provided by the resistances R_b. The inductances L_5 and L_7 may consist of simple solenoids of a few turns and should be placed with their axes at right angles and not too near together in order to avoid any appreciable mutual inductance which would modify the action of the filter. The coils L_h may also be solenoids not too closely wound in order to reduce the self capacity. Each of the condensers K can usually be provided by means of a small plate fixed to the screen of the amplifier and insulated therefrom by a sheet of mica or the like. Q_t and Q_i can be small rotary air condensers of conventional type.

The filter according to Fig. 5 may be constructed in another way. It is well known that the network of the three inductances L_5, L_7 and L_8 is equivalent to a two-winding transformer. This figure can therefore be redrawn as Fig. 8, in which L_9 and L_{10} are the inductances of the two transformer windings, and M is the mutual inductance between them.

The equivalence of these two networks is discussed in the article by E. K. Sandeman entitled "Coupling Circuits as Band Pass Filters" in the "Wireless Engineer," vol. XVIII, No. 216, September, 1941, pages 363 to 365. From the formulae given in that article, it follows that for the conditions of the present case:

$$\left.\begin{aligned} L_9&=R_t(\omega_2-\omega_1)(\omega_2^2+\omega_1^2)/2\omega_1^2\omega_2^2 \\ L_{10}&=n^2L_9 \\ &\text{and} \\ M&=nR_t(\omega_2-\omega_1)(\omega_2^2-\omega_1^2)/2\omega_1^2\omega_2^2 \end{aligned}\right\} \quad (10)$$

C_2 and C_3 having the same values as before. It is to be noted that realisable values of L_9, L_{10} and M can be chosen for any desired values of ω_1 and ω_2 so that the restrictions inherent in the network of Fig. 5 do not apply to Fig. 8. The values of n and R_t are of course determined when C_t and $\omega_2-\omega_0$ are specified, just as in the case of Fig. 5, and the maximum gain obtainable is the same.

If the same numerical case as before be taken, using the same type of valve, then $n^2=0.0945$ and $Rt=2340$ ohms, $\omega_2/2\pi=147$ and $\omega_1/2\pi=107$; then substituting in Equation 10 it is found that:

$L_9=0.996$ microhenry
$L_{10}=0.0941$ microhenry
$M=0.0940$ microhenry

the values of C_2 and C_3 being the same as before.

In order to illustrate a case in which the filter of Fig. 5 would be unrealisable, while Fig. 8 would be possible, suppose that a wider band be taken, and let

$$\omega_1/2\pi=100 \text{ megacycles}$$

and

$$\omega_2/2\pi=150 \text{ megacycles}$$

the same valve being used. From Equation 6 $Rt=1872$ ohms, and from Equation 2 $n^2=0.1156$ giving a gain of about 9.4 db. instead of about 10.2 db. for the narrower band. Thence from Equations 10

$L_9=1.076$ microhenry
$L_{10}=0.1245$ microhenry
$M=0.1408$ microhenry

the value of C_2 is of course the same as before, namely 1.7 micro-microfarads, but C_3 is now smaller and equal to about 14.7 micro-microfarads, on account of the larger value of n^2.

Fig. 9 shows a schematic diagram of a practical arrangement employing the filter of Fig. 8. This arrangement is similar to Fig. 7 and those elements which are the same in both figures are similarly designated and will not be again described. In Fig. 9, the anode voltage for the valve V_1 is supplied through the winding L_9 of the transformer, and current for the cathode heater is fed through L_{10} so that only one choke coil L_h is needed for the other heater lead. Also no blocking condenser corresponding to H in Fig. 7 is required.

The network of Fig. 5 may also be realised in a different way by supplying the inductance elements in the form of short sections of co-axial transmission lines. The manner in which this may be done is fully explained in the specification of U. S. Patent 2,284,529. The configuration described with reference to Fig. 2 of that specification would be suitable in the case of the present invention. Fig. 6 might also be suitable, since it produces the star arrangement of the three inductances which is equivalent to the delta arrangement of the accompanying Fig. 5. It is pointed out in the specification referred to that the lengths of the line sections used should be less than about one eighth of the shortest wavelength evolved so that the line sections operate substantially as lumped inductive elements. The necessary formulae for dimensioning the line sections are given in U. S. Patent 2,284,529 so they will not be quoted again here.

The accompanying Fig. 10 shows the manner in which the transmission lines arranged as in Fig. 2 of Patent 2,284,529 may be applied to the present invention. The two valves V_1 and V_2 are arranged inside a tube 1, only part of which is shown. The valves are preferably of the type having a disc terminal for the grid, and this is arranged so that the grid with its disc forms substantially a perforated partition across the tube. The anode of V_1 is connected to the cathode of V_2 by a conductor 2 coaxial with the tube 1 and divided by a blocking condenser H. This constitutes the inductance L_5 of Fig. 5. Two side tubes 3 and 4 are provided, the central conductor 5 of tube 3 being connected to the anode end of conductor 2 and passing out of the tube 3 at the closed end. A plate 6 insulated from the end of the tube forms a bypass condenser. The conductor 5 is connected to the anode supply source. The central conductor of the tube 4 is a tube 7 connected to the cathode end of the conductor 2, and the second heater conductor 8 passes through this tube and out through the closed end of the tube 4. A flange 9 attached to the tube 7 forms the necessary bypass condenser, and a lead 10 connected to the flange 9 also passes outside the tube 4. Leads 8 and 10 are connected to the cathode heating source HS. The condensers Q_t and Q_i are supplied as before, and are connected between the wall of the tube 1 and the anode and cathode, respectively. A resistance 11 is provided for biassing the cathode of V_2.

The tubes 3 and 4 with their central conductors constitute the inductances L_8 and L_7 of Fig. 5.

In the case where there are several more similar amplifying stages, all the valves may be assembled inside the tube 1, each pair of successive valves being connected by an exactly similar arrangement of two side tubes like 3 and 4, and a central conductor similar to 2 containing a blocking condenser H.

If it is desired to reproduce in this form the filter of Fig. 6, the side tube 3 is omitted, as shown in Fig. 11. The central conductor 7 of the side tube 4 is connected to the central conductor 2 which in this case has no blocking condenser dividing it into two parts. The high tension for the anode of V_1 is supplied through the conductors 7 and 2. Both the cathode heater leads 10 and 12 for the valve V_2 are passed through the conductor 7, but both ends of the heater are coupled thereto by bypass condensers K. The remaining elements of Fig. 11 which have not been mentioned are the same as in Fig. 10.

What is claimed is:

1. An electric wave amplifier comprising two thermionic tubes each having a cathode and an anode, a hollow conductor having said tubes mounted therein, a grounded grid in each of said tubes directly connected to said hollow conductor and forming a substantially perforated partition thereacross, two conductors mounted inside said hollow conductor between said tubes and forming a coaxial conductor line with said hollow conductor, a direct current blocking condenser connecting said two conductors together, said two conductors being directly connected one to the anode of one of said tubes and the other to the cathode of the other of said tubes, and two quarter wave coaxial line type stubs connected across said coaxial conductor, one adjacent said one tube and the other adjacent said other tube, said stubs being dimensioned to inductively load said coaxial conductor, said coaxial conductor being dimensioned to couple inductively said tubes together, the input and output inter-electrode capacities of said tubes forming with the coaxial elements a transforming filter adapted to pass a frequency band of given band width.

2. An amplifier according to claim 1 in which the inner conductor of each of said coaxial line type stubs is insulated from the outer and directly connected one to the anode of said one tube and the other to the cathode of said other tube for applying operating potentials thereto.

3. An amplifier according to claim 1 in which additional capacities are respectively connected in shunt between the anode and grid of said one tube and between the cathode and grid of each other tube.

4. An electric wave amplifier comprising two thermionic tubes each having a cathode and an anode, a hollow conductor having said tubes mounted therein, a grounded grid in each of said tubes directly connected to said hollow conductor and forming a substantially perforated partition thereacross, two conductors mounted inside said hollow conductor between said tubes and forming a coaxial conductor line with said hollow conductor, said two conductors being directly connected one to the anode of one of said tubes and the other to the cathode of the other of said tubes and a blocking condenser coupling said two conductors together, a coaxial line type stub connected across said coaxial conductor line, said stub being dimensioned to inductively load said coaxial line, said coaxial line being dimensioned to inductively couple said tubes, the input and output inter-electrode capacities of said tubes forming with the coaxial elements a transforming filter adapted to pass a frequency band of given band width.

5. An amplifier according to claim 4 in which the inner conductor of said coaxial line type stub is hollow and insulated from the outer conductor thereof and directly connected to the anode of said one tube for applying an operating potential thereto, and an additional conductor is arranged inside said hollow conductor and directly connected to the anode of said other tube for applying an operating potential thereto.

6. An amplifier according to claim 4 further comprising additional capacities connected in shunt between the anode and grid of said one tube and between the cathode and grid of said other tube.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,896,534	Alexanderson	Feb. 7, 1933
2,107,387	Potter	Feb. 8, 1938
2,143,671	Zottu	Jan. 10, 1939
2,149,356	Mason	Mar. 7, 1939
2,284,529	Mason	May 26, 1942
2,321,521	Salinger	June 8, 1943
2,419,800	Tomlin	Apr. 29, 1947
2,426,185	Doherty	Aug. 26, 1947

OTHER REFERENCES

Article by Jones, Proceedings of the I. R. E., July 1944, vol. 32, No. 7, pp. 423–429, reprint in 179—171—1.