May 27, 1941. A. PREISMAN 2,243,121

AMPLIFYING SYSTEM

Filed April 1, 1938 2 Sheets-Sheet 1

Fig. 1

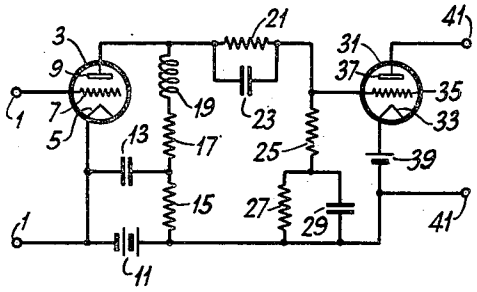


Fig. 4

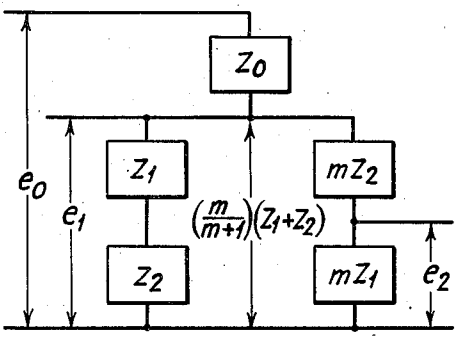


Fig. 2

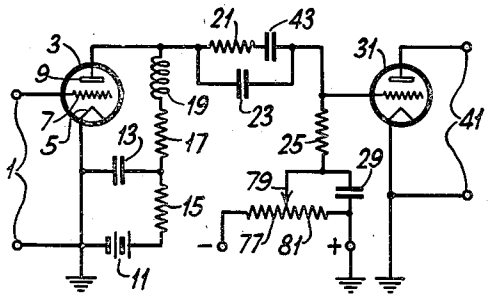


Fig. 5

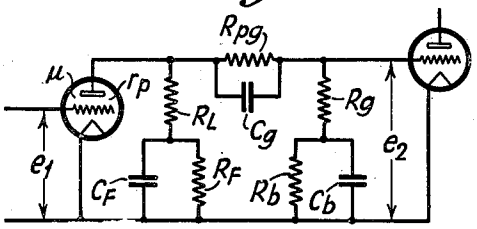


Fig. 3

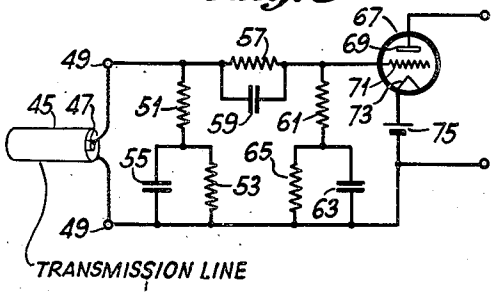
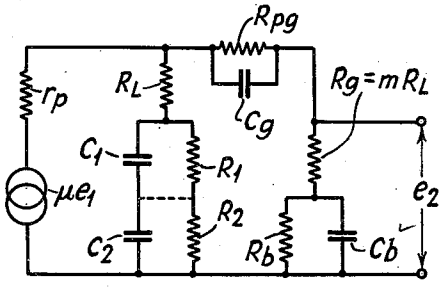


Fig. 6



INVENTOR.
ALBERT PREISMAN

BY

ATTORNEY.

May 27, 1941. A. PREISMAN 2,243,121

AMPLIFYING SYSTEM

Filed April 1, 1938 2 Sheets-Sheet 2

Fig. 7

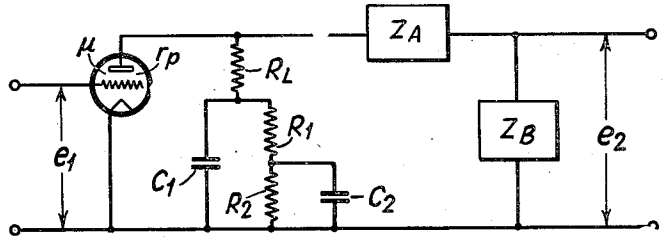


Fig. 8

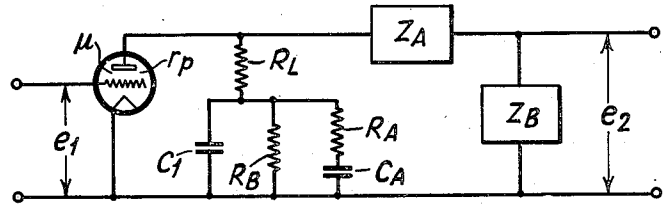


Fig. 9

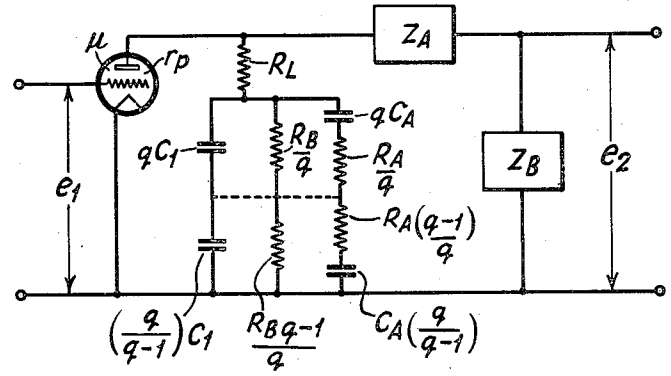


Fig. 10

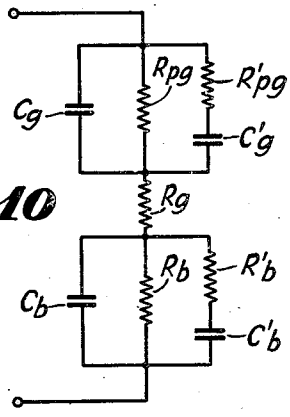
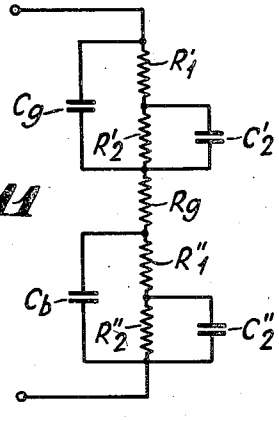


Fig. 11



INVENTOR.
ALBERT PREISMAN

BY

ATTORNEY.

Patented May 27, 1941

2,243,121

UNITED STATES PATENT OFFICE

2,243,121

AMPLIFYING SYSTEM

Albert Preisman, Bronx, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application April 1, 1938, Serial No. 199,337

9 Claims. (Cl. 179—171)

This invention relates to amplifying systems, and more particularly, to amplifying systems having substantially uniform amplification over an exceedingly wide frequency band, together with zero phase delay shift. Such amplifiers are free from phase distortion as a function of frequency throughout the response range.

Such amplifiers are of considerable importance in television where it is necessary to transmit all frequencies from zero up to 5 megacycles or more. In accordance with the invention, amplifying systems having a plurality of stages have their plate circuit constants so chosen with respect to the grid circuit constants of the following stage, that perfect freedom from phase distortion is obtained. It is well recognized that in wide band amplifiers such as those required for use in television, in contra-distinction to amplifying systems for sound, the phase relation between input and output of the various frequency components present in the video signals must be rigorously maintained because any relative phase displacement between these components results in a loss of definition in the reproduced picture. In this connection, it is exceedingly important that the low frequency components have their initial phase relation with respect to the higher frequency components free from any variation or deviation, since the low frequency components represent the background values, while the high frequency components determine the sharpness or resolution of the reproduced image. Any phase displacement between these two sets of components destroys the sharpness of detail, inasmuch as the high frequency components do not coincide in proper spatial relation with the background so that instead of a sharp and clear image, a "fuzzy" image is reproduced. By properly choosing the constants of the plate circuit and the grid circuit of the following stage in accordance with the invention, it is possible to provide an amplifying system which is completely free from such phase distortion and at the same time to improve and increase the overall gain of the amplifier, even when conventional triode thermionic amplifying tubes are used.

It is further well known that the upper frequency limit of such amplifiers is generally determined by the inter-electrode capacities of the tubes, and in order to avoid amplitude distortion, relatively low plate impedances must be used so that the shunting capacities may not seriously affect the amplification adversely. Under such conditions, in order to obtain sufficient gain, the prior art has made frequent attempts to use pentode thermionic amplifiers. By the use of the present invention, amplifiers using triode thermionic tubes are capable of giving the increased gain over that of the pentode and at the same time are capable of maintaining uniformity of amplitude output over the entire frequency range. Further, in accordance with the invention, by taking into account the power supply filter circuits, as well as the coupling circuits of the amplifiers, the grid circuit impedance does not influence the amplitude-frequency response of the amplifier, but only affects the gain.

It is further possible, in accordance with the invention, to obtain substantially perfect compensation, even with low coupling resistances, which was not possible in the prior art. Under certain conditions, especially where tubes of very high trans-conductance are used, it is necessary to provide low decoupling resistances so that the potential drop across the resistance will not be excessive and require, in turn, excessively high plate supply voltages. Where this was done in the prior art, violent transients arose in operation, due to imperfect correction of the phase of the amplified currents. With the present invention, however, this is completely avoided so that high trans-conductance thermionic amplifiers can be used with conventional plate supply voltages, and yet provide substantially perfect freedom from any phase distortion.

The invention further provides the means for feeding an amplifier from a transmission line, such as a coaxial cable, without suffering any phase distortion from this connection due to reflections and improper terminations by inserting between the transmission line and grid circuit, a network representing an equivalent plate circuit network.

These features of the invention herein to be described in detail, are obtained by taking into account the filter circuit of the power supply feeding the plate circuit of a thermionic tube which the prior art disregarded, as well as the plate load impedance, and by selecting the grid coupling and grid circuit network of the following thermionic amplifier so that it is similar in its impedance characterstic to the combined plate load-plate filter circuit. By making the two networks similar in their impedance characteristics, the phase angle of the energy components fed between the grid and cathode of the second thermionic amplifier is identical with the phase angle of the energy components im-

pressed across the input of the first thermionic tube. Accordingly, the amplifier cannot introduce any phase distortion between the various energy components, while at the same time it provides uniform amplitude of amplified energy.

It is thus the main object of this invention to provide a new and improved amplifying system which has substantially uniform amplitude and phase characteristics throughout the entire wide band of frequencies necessary to transmit high detail television images, although the same general form system is applicable because of its uniformity and flat characteristic to all types of amplifiers.

Another object of this invention is to provide an amplifying system having a plurality of stages in which the plate load-plate filter circuit of one thermionic tube is made to have similar impedance characteristics to the grid coupling-grid circuit network of a following thermionic amplifier.

Still another object of this invention is to provide an amplifying system in which perfect phase compensation can be obtained even with low decoupling plate filter resistances.

Another object of this invention is to provide an amplifying system in which the frequency characteristic of the amplifier is independent of the grid circuit impedance of the thermionic amplifier comprised within the amplifying system.

Other objects and improvements of my invention will be ascertained upon a reading of the following description taken together with the drawings.

In the drawings, Fig. 1 shows schematically a circuit comprising a two-stage amplifier embodying the circuit arrangement of the invention;

Fig. 2 shows schematically a modification of the embodiment shown in Fig. 1, in which the D. C. component is not transmitted and where the grid circuit includes a grid bias filter;

Fig. 3 shows another embodiment of my invention wherein a transmission line such as a coaxial cable, is used to feed the first stage of an amplifying system.

Figs. 4, 5 and 6 show diagrammatically equivalent circuits of that shown in Fig. 1 for purpose of explaining the invention and deriving the necessary conditions and relationships between the circuit constants;

Figs. 7, 8, 9, 10 and 11 are schematic representations of a further embodiment and modification of my invention useful where a two-section plate filter is used, in contradistinction to the single section plate filter shown in Figs. 1 and 2.

Turning now to the drawings, the invention will be explained in detail as to the constituent parts and their functioning. In Fig. 1 there is shown a two-stage amplifier, although it is to be understood that more stages may be provided as well as less stages, such as, for example, the single stage amplifier shown in Fig. 3. In Fig. 1 the input signal comprising a plurality of frequencies is impressed on the terminals 1 so as to actuate the grid 7, cathode 5, circuit of the tube 3. In the plate 9 circuit is connected serially an inductance 19, commonly called a "peaking coil," and a plate load resistance 17 to the filter of decoupling circuit comprising the resistance 15 and condenser 13 connected to the battery 11 which supplies the plate circuit. The second stage of the amplifier comprising the thermionic triode 31 is coupled from the preceding tube 3 through a parallelly connected resistance 21 and condenser 23, and the grid 35 of the tube 31 is connected to one side of the resistance 25, the other side of the resistance being connected to a parallelly connected resistance 27 and condenser 29, which in turn is connected to a bias battery 39, said bias battery being connected to cathode 33. The load circuit is connected appropriately to the terminals 41.

In accordance with the invention, the elements 13, 15, 17 and 19 having been chosen, the constants 21, 23, 25, 27 and 29 are determined in accordance with the principles as will be outlined below so that the grid network comprising the grid coupling resistance and condenser 21 and 23, respectively, and the grid circuit comprising the elements 25, 27 and 29, are similar in impedance characteristic to the plate circuit, differing therefrom only in magnitude by a real number. Under such conditions, the energy components impressed between the grid 35 and cathode 33 of the tube 31 will have identical phase relation with respect to each other as the energy components impressed between the grid 7 and cathode 5 of the amplifier 3.

In order to show what this relationship must be, reference will be made to Fig. 4 in which Z_0 represents the dynamic plate impedance, Z_1 represents the plate load together with an equivalent portion of the plate supply filter, Z_2 represents the difference between the values of the plate filter and the equivalent portion of the plate filter included in Z_1. mZ_2 represents the grid coupling circuit and mZ_1 is equivalent to the grid resistance plus the parallelly connected condenser and resistance connected thereto between the grid and cathode. e_0 represents the voltage impressed by the tube, while e_1 represents the voltage appearing between the plate and cathode. e_2 represents the voltage impressed between the grid and cathode of the following stage. It will readily be seen in accordance with application of elementary circuit analysis, such as Kirchhoff's laws, that

$$e_1 = e_0\left[\frac{\left(\frac{m}{m+1}\right)(Z_1+Z_2)}{Z_0+\left(\frac{m}{m+1}\right)(Z_1+Z_2)}\right] \quad (1)$$

Likewise,

$$e_2 = e_1\left[\frac{mZ_1}{m(Z_1+Z_2)}\right] \quad (2)$$

and substituting for e_1, we obtain:

$$e_2 = e_0\left[\frac{\left(\frac{m}{m+1}\right)Z_1}{Z_0+\left(\frac{m}{m+1}\right)(Z_1+Z_2)}\right] \quad (3)$$

If now we chose the impedances such that

$$Z_1 = S\left[Z_0+\left(\frac{m}{m+1}\right)(Z_1+Z_2)\right] \quad (4$$

where S is any real number, it will be noted that by substituting the value of Z_1 in Equation 4, for Z_1 in Equation 3, then

$$C_2 = C_0 S\left(\frac{m}{m+1}\right) \quad (5)$$

It will be noted from the above equation that the numerator is equal to the denominator, and

these cancel out, except for the terms S and those including m. m is likewise a constant and real number and is chosen as will be pointed out below, as the ratio between the load resistance and the total grid resistance. Under such circumstances, it will be at once apparent that e_2, that is, the voltage impressed across the grid circuit of the second tube, is equal to the grid voltage impressed across the grid circuit of the first tube multiplied only by a real number. Accordingly, the voltage impressed upon the grid of the second tube is independent of frequency and thus the amplification cannot introduce any phase distortion. Thus it only remains to show the relationship which must be provided in order that the grid circuit elements shall be similar to those of the plate circuit elements.

To facilitate this, reference is made to Fig. 5 in which for convenience, the circuit shown in Fig. 1 has been simplified. In order that the plate circuit may be similar to the grid circuit, the branch of the plate load circuit must be broken up into two parts in such a manner that part of C_F and R_F can be associated with R_L to form Z_1 and the remainder to form Z_2. Then C_g and R_{pg} will be made m times the latter, and R_g together with R_b and C_b will be made equal to m times Z_1. It will be noted that Z_0 is equivalent to r_p and e_0 is here μe_1, so that the breaking up of C and F into component parts is such as to satisfy Equation 4.

In Fig. 6 there is shown the partition of the circuit C_f and R_f which corresponds to the elements 13 and 15 shown in Fig. 1 in their component parts. By so choosing

$$\frac{C_2}{C_1}=\frac{R_1}{R_2}$$

it will be apparent that there is provided the equivalent of a Wheatstone bridge and that no current will flow along the path indicated by the dotted line from the junction point of the two condensers and the junction point of the two resistances, since the bridge is balanced. Accordingly, these two points may be short-circuited.

It will thus be apparent that a further equivalent bridge is provided in which one arm C_2—R_2 has the equivalent characteristics of the diagonal arm R_{pg}—C_g while the arm comprising R_L connected in series with the parallelly connected C_1 and R_1 is equivalent to the diagonal arm comprising R_g, R_b, and C_b. In this connection it is to be noted that the series inductance or peaking coil is effective only at the very highest of frequencies, and so at the low frequencies, can be neglected and, consequently, is not shown in Figs. 5 and 6. At the very high frequencies at which the peaking coil becomes effective, the various capacities as C_1, C_2, C_b, and C_g have exceedingly low reactance and consequently, the amplifying system acts as though it was purely resistance coupled, and consequently, substantially no phase distortion is introduced even at these frequencies. It is well known in the prior art that such peaking coils together with their distributed capacity, are worked within the region at which substantially no phase shift distortion between the various frequency components of the energy amplified is introduced, so that the neglect of the taking into account the inductance in the plate circuit does not invalidate the results and conclusions above given.

The determination of the various parameters is governed by the following conditions.

(1) The high frequency response of the stage determines the value of R_L and the peaking coil in series with it. Hence the ratio

$$\frac{R_L}{r_p}=k$$

is determined by the high frequency response. Experience has shown that this ratio is of the order of 1/5.

(2) The values of R_F and C_F are determined by feedback considerations and must be large enough to prevent motor-boating in multi-stage units. Commonly used values are on the order of 10,000 ohms and 8 micro-farads respectively.

(3) The maximum value of m is determined by the value of R_L and the total grid resistance R_g and R_b. The total grid resistance comprising R_g and R_b in turn is determined by the amount of the so-called grid gas current, i. e. the small value of grid current which flows between grid and cathode, even when the tube is biased negatively. Generally this resistance cannot exceed one megohm in order to prevent the grid current from affecting adversely the amplification characteristic of the amplifying system. Small values of m are permissible, however, and may even be desirable in certain cases.

(4) With the above values fixed by external considerations, we can now determine the values of R_{pg}, C_g, R_g, R_b, and C_b. By algebraic manipulation it can be shown that

$$C_g=C_F\left[\frac{m+1+mk}{m(m+1)}\right] \tag{6}$$

$$R_{pg}=R_F\left[\frac{m(m+1)}{m+1+mk}\right] \tag{7}$$

$$R_g=mR_L \tag{8}$$

$$C_b=C_F\left[\frac{m+1+mk}{m^2k}\right] \tag{9}$$

$$R_b=R_F\left[\frac{m^2k}{m+1+mk}\right] \tag{10}$$

and the gain will be equal to

$$G=\mu\left[\frac{mk}{m+1+mk}\right] \tag{11}$$

An example will indicate the range of values to be expected for the various parameters. Thus, assume r_p=10,000 ohms—a usual value for a triode. Suppose for proper high frequency response, R_L must be 2,000 ohms. Then k=0.2. Assume that necessary values for C_F and R_F are 8 mfds. and 10,000 ohms respectively, and that m can be 100. Then, applying Equations 6, 7, 8, 9, 10 and 11, we find

$$C_g=8\times\left[\frac{100+1+20}{100(100+1)}\right]=0.0951 \text{ mfd.}$$

$$R_{pg}=10{,}000\left[\frac{100(100+1)}{100+1+20}\right]=834{,}000 \text{ ohms}$$

$$R_g=100\times 2{,}000=200{,}000 \text{ ohms}$$

$$C_b=8\times\left[\frac{100+1+20}{(100)^2(0.2)}\right]=0.484 \text{ mfd.}$$

$$R_b=1000\left[\frac{(100)^2(0.2)}{100+1+20}\right]=165{,}200 \text{ ohms}$$

$$G=\mu\left[\frac{100\times 0.2}{100+1+20}\right]=\mu(0.1652)$$

A special case arises when k is approximately zero, which arises upon the substitution of a pentode tube for a triode. In such case, the internal impedance being so very high, makes

$$\frac{R_L}{r_p}$$

very small, so that k is approximately zero. In such a case, it will be found that C_b and R_b likewise become zero, and drop out of consideration and that C_g reduces to

$$\frac{C_F}{m}$$

and $R_{pg}=m(R_F)$, while R_g remains equal to mR_L. Accordingly, if it is desired to use pentodes in place of triodes, the circuit elements **27** and **29** shown in Fig. 1 can be eliminated.

Where it is not necessary to amplify the D. C. component, representing the average light value, the circuit arrangement shown in Fig. 2 may be used, in which the elements bearing the same number are identical to those shown in Fig. 1. It will be noted in this case, that a blocking condenser **43** is provided in series with the grid coupling resistance **21**. The value of this capacity is made relatively large so that its impedance is negligible compared with the resistance of the resistor **21**. In the example cited above, a condenser of $\frac{1}{10}$ of a micro-farad would have negligible reactance compared to the calculated 834,000 ohm resistance down to 15 cycles. Sufficiently below this frequency, however, the effect would be attenuation of response, together with appreciable phase shift. At the same time, it is to be noted that in Fig. 2 a power-pack bias supply is shown for tube **31**. In this case, the bias determined by the position of the tap **79** on the voltage divider **77** includes resistance **81** and this resistance is equivalent to the resistance **27** shown in Fig. 1. By appropriately choosing this value to coincide with that determined above as R_b, the conditions necessary to give freedom from phase distortion is met.

A further advantage rises from the use of the circuit shown in Fig. 2 where it is unnecessary to transmit frequencies below 15 cycles in that the characteristic indicates a fairly sharp cut-off below 15 cycles, in which region motor-boating is most apt to take place, so that the circuit shown in Fig. 2 provides the additional advantage of effectively supplying more filtering and freedom from self-oscillation of the amplifier.

It is evident from the above that if freedom from phase distortion is to be obtained in accordance with the invention, the grid of one tube cannot be used to compensate for the latter's plate circuit, but that the grid circuit of the following tube must be used for this purpose. If the input circuit of the first stage of a multi-stage amplifier is to be fed from a source, as a coaxial cable, then for perfect compensation an artificial plate circuit network must be used to terminate the line from which the grid is appropriately fed. Such a connection is shown in Fig. 3, where the artificial plate circuit is shown as the elements **51, 53** and **55**, together with the coupling circuit **57, 59**. In such a case, the characteristic impedance of the coaxial cable **45** replaces, or can be substituted for Z_0 in the discussion above, or for r_p as shown in Fig. 5.

If a two section decoupling circuit be employed, as shown in Figure 7, then the grid coupling circuit can be determined as follows:

The decoupling circuit can be transformed into an equivalent circuit. This results in a circuit shown in Figure 8.

This circuit can then be broken up as shown in Figure 9. Then Z_A is made m times the impedance of the bottom portion, and Z_B is made m times R_L plus the top portion. Then q is determined so that Equation 4 is satisfied. The result is a grid circuit of the form shown in Figure 10. This may be transformed into an equivalent form shown in Figure 11.

The values of the various parameters are as follows:

For Figure 10:

$$C_g=C_1\left[\frac{m+1+mk}{m(m+1)}\right] \tag{12}$$

$$R_{pg}=(R_1+R_2)\left[\frac{m(m+1)}{m+1+mk}\right] \tag{13}$$

$$R_g=mR_L \tag{14}$$

$$C'_g=\left[\frac{m+1+mk}{m(m+1)}\right]\frac{C_2}{\left(1+\frac{R_1}{R_2}\right)^2} \tag{15}$$

$$R'_{pg}=\left[\frac{m(m+1)}{m+1+mk}\right]\left(\frac{R_1}{R_2}\right)(R_1+R_2) \tag{16}$$

$$C_b=C_1\left[\frac{m+1+mk}{m^2k}\right] \tag{17}$$

$$R_b=\left[\frac{(R_1+R_2)\,m^2k}{(m+1+mk)}\right] \tag{18}$$

$$R'_b=\left(\frac{R_1}{R_2}\right)\frac{(R_1+R_2)\,m^2k)}{(m+1+mk)} \tag{19}$$

$$C'_b=\left[\frac{m+1+mk}{m^2k}\right]\frac{C_2}{\left(1+\frac{R_1}{R_2}\right)^2} \tag{20}$$

For Figure 11:

$$C_g=C_1\left[\frac{m+1+mk}{m^2k}\right] \tag{21}$$

$$R'_1=R_1\left[\frac{m(m+1)}{m+1+mk}\right] \tag{22}$$

$$R'_2=R_2\left[\frac{m(m+1)}{m+1+mk}\right] \tag{23}$$

$$C'_2=C_2\left[\frac{m(m+1)}{m+1+mk}\right] \tag{24}$$

$$R_g=mR_L \tag{25}$$

$$R''_1=R_1\left[\frac{m^2k}{m+1+mk}\right] \tag{26}$$

$$R''_2=R_2\left[\frac{m^2k}{m+1+mk}\right] \tag{27}$$

$$C''_2=C_2\left[\frac{m+1+mk}{m^2k}\right] \tag{28}$$

$$G=\mu\left[\frac{mk}{m+1+mk}\right] \tag{29}$$

In all these formulas $k=R_L/r_p$.

At this point it may be well to point out that the grid coupling circuit of Figure 2 can also be transformed, if desired, into equivalent circuit similar to that shown in Figure 10.

It will be noted here that if k is very small, the lower network in the grid coupling circuit will again drop out as was discussed above in connection with the use of a pentode in place of the triode shown in Fig. 1, and at the same time, the upper network approaches m times the plate decoupling circuit.

That the use of the triode provides a greater gain than the use of a pentode, can be seen from the fact that where a pentode is used, the gain may be shown to be equal to

$$G=\mu\left[\frac{mk}{m+1+mk+k}\right] \qquad (30)$$

Comparing Equation 30 with Equation 11, which gives the gain for the triode tube, it will be noted that the denominator of Equation 30 includes in its sum the addition term k, which factor is not present in that of the denominator showing the gain for the triode, and hence, since k is a real positive number, the denominator of Equation 30 must be larger, with the result that the gain is smaller than that given by Equation 11.

It will be further noted that no limitation is placed on how low the grid coupling impedance may be as far as frequency response is concerned. The only effect of a low grid coupling impedance will be a reduction in the gain. It is further to be noted that the circuits described above enable perfect compensation to be obtained, even if the decoupling time constant is low, and this, together with the use of triode tubes and providing, at the same time, higher gains than can be realized from pentodes, affords a superior amplifying system, particularly useful for wide band amplification.

Having described my invention, what I claim is:

1. In an amplifying system wherein is provided a thermionic tube having a cathode, control electrode, and anode, the method of preventing phase distortion in the system which comprises providing a first complex bifurcated impedance path between the cathode and control electrode one of the forks of said bifurcated path varying substantially with frequency, providing energy to be amplified from a source of energy having a plurality of frequency components, and interposing between the source of energy and the first complex impedance path a second complex bifurcated impedance path whose impedance differs only in magnitude by a real number from the impedance of the first impedance path.

2. In an amplifying system wherein is provided two thermionic tubes each having a cathode, grid, and anode, the method of avoiding phase distortion which comprises providing a complex bifurcated impedance path between the anode and cathode of one of said tubes, one of the forks of said bifurcated path varying substantially with frequency, supplying energy to the complex impedance path through the named tube, supplying a similar complex bifurcated impedance path whose impedance differs only in magnitude by a real number from the impedance of the first named impedance path, and energizing the grid and cathode of the other of the two tubes through the similar complex impedance path from the first named complex impedance path.

3. An amplifying system for preventing phase distortion comprising a thermionic tube having a cathode, control electrode, and anode, means for providing a first complex impedance path including parallelly connected current conducting elements between the cathode and control electrode, one of said elements varying substantially with frequency and another of said elements being substantially independent of frequency, means for providing energy to be amplified from a source of energy having a plurality of frequency components, and means for interposing between the source of energy and the first complex impedance path a second complex impedance path whose impedance is similar to and differs only in magnitude by a real number from the impedance of the first impedance path.

4. An amplifying system for preventing phase distortion comprising two thermionic tubes each having a cathode, grid, and anode, means for providing a complex impedance path including parallelly connected current conducting elements between the anode and cathode of one of said tubes, one of said elements varying substantially with frequency and another of said elements being substantially independent of frequency, means for supplying energy to the complex impedance path, means for supplying a similar complex impedance path whose impedance differs only in magnitude by a real number from the impedance of the first named complex impedance path, and means for energizing the grid and cathode of the other of the two tubes through the similar complex impedance path.

5. An amplifying system comprising a thermionic tube having an input circuit, a cathode, anode, and control electrode, an inductance connected in series with a resistance, decoupling resistance, and condenser, between the anode and cathode, a second thermionic tube having a cathode, control electrode and anode, a parallelly connected capacity and resistance between the anode of the first named thermionic tube and the control electrode of the second thermionic tube, and a serially connected resistance and decoupling resistance and capacity connected between the grid and cathode of the second thermionic tube whereby phase distortion in the amplifier is prevented.

6. An amplifying system comprising a transmission line, a thermionic amplifier having a cathode, control electrode and anode, a resistance connected in series with a decoupling resistance and capacity connected between the grid and cathode of the thermionic tube, and a complex impedance network having a shunt and series arm, said shunt arm comprising a resistance connected in series with a parallelly connected resistance and capacity, and said series arm comprising a parallelly connected resistance and capacity connected between the transmission line and the control electrode and cathode of the thermionic tube.

7. In an amplifying system wherein is provided two thermionic tubes to be connected in cascade and in which each thermionic tube has output electrodes and input electrode, the method of amplifying energy substantially free from amplitude and phase distortion, which comprises the steps of providing a complex bifurcated impedance path between the output electrodes of one of said tubes, providing between the input electrodes of the other of said tubes a similar complex bifurcated impedance path whose impedance differs only in magnitude by a real number from the impedance of the first named complex impedance path, and supplying from the output electrodes of the first of said tubes energy to the input electrodes of the other of said tubes.

8. An amplifying system comprising two thermionic tubes connected in cascade and hav-

ing output and input electrodes, means for providing a complex path including parallelly connected current conducting elements between the output electrodes of one of said tubes, one of said elements varying substantially with frequency and another of said elements being substantially independent of frequency, means for providing between the input electrodes of the other of said tubes a similar complex impedance path whose impedance differs only in magnitude by a real number from the impedance of the first named complex impedance path, and means for supplying from the output electrodes of the first of said tubes energy to the input electrodes of the other of said tubes.

9. An amplifying system comprising a thermionic tube having an input circuit, a cathode, anode, and control electrode, an inductance connected in series with a resistance, two decoupling resistances and condensers, between the anode and cathode, a second thermionic tube having a cathode, control electrode and anode, a parallelly connected capacity and resistance between the anode of the first named thermionic tube and control electrode of the second thermionic tube, and a serially connected resistance and two decoupling resistances and capacities connected between the grid and cathode of the second thermionic tube whereby phase distortion in the amplifier is prevented.

ALBERT PREISMAN.