

Aug. 30, 1949.

K. POSTHUMUS
HIGH-FREQUENCY AMPLIFIER WITH
CONTROLLED LOAD IMPEDANCE

2,480,195

Filed May 1, 1946

2 Sheets-Sheet 1

Fig. 1.

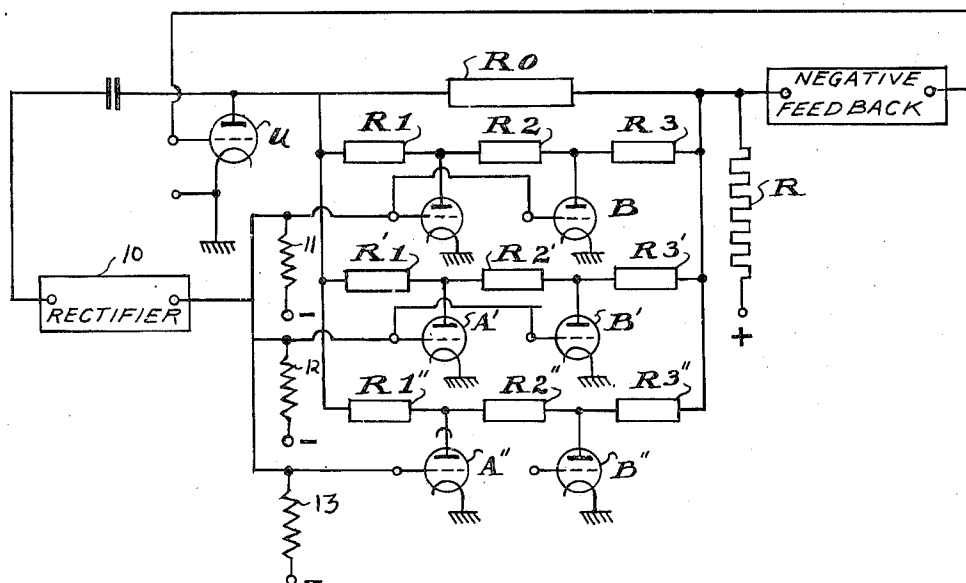
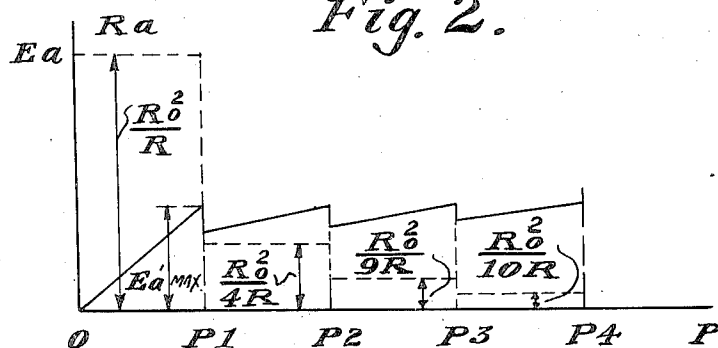


Fig. 2.



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2 Sheets-Sheet 2

Fig. 3.

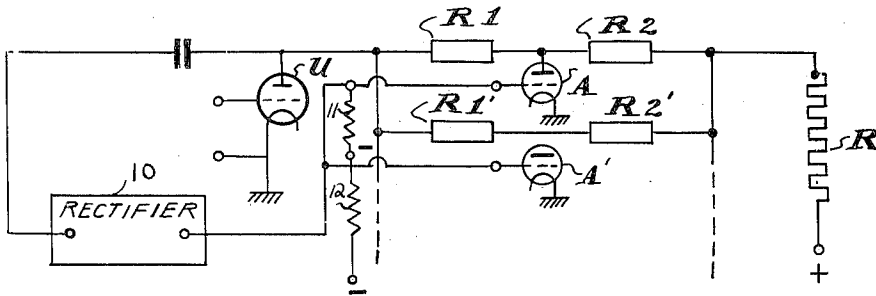
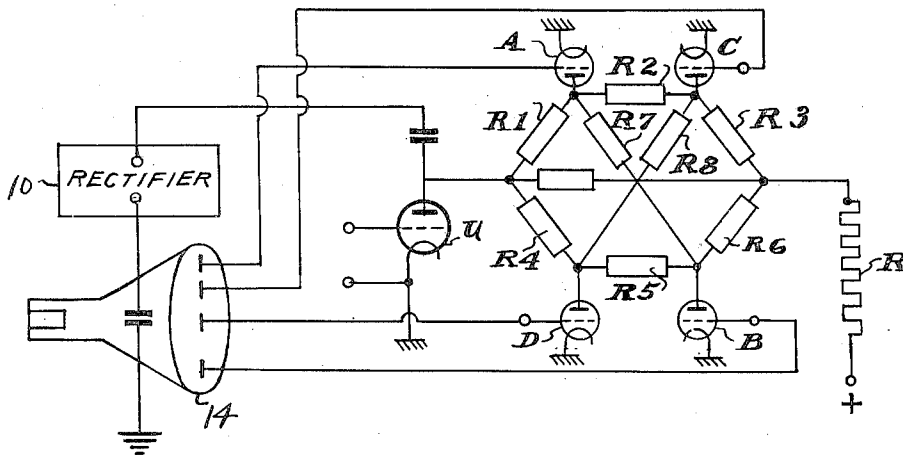


Fig. 4.



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UNITED STATES PATENT OFFICE

2,480,195

HIGH-FREQUENCY AMPLIFIER WITH
CONTROLLED LOAD IMPEDANCE

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Application May 1, 1946, Serial No. 666,239
In the Netherlands January 10, 1942

Section 1, Public Law 690, August 8, 1946
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9 Claims. (Cl. 179-171)

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This invention relates to a device for amplifying modulated high-frequency oscillations which comprises at least one amplifier valve and which is especially suitable for the final stage of a transmitter.

For amplifying modulated high-frequency oscillations it is known to make use of an amplifier valve whose grid bias is so high that during half each cycle of the alternating voltage to be amplified the valve allows current to pass. Such an amplifier is known as a B-amplifier and at full load it has an efficiency of

$$\frac{\pi}{4}$$

if the amplitude of the alternating voltage occurring in the output circuit is assumed to be equal to the anode direct voltage. In practice, however, is permitted a maximum amplitude of the anode alternating voltage which is equal to from 0.8 to 0.9 times the anode direct voltage so that in practice the maximum efficiency of a B-amplifier does not exceed from

$$0.8 \text{ to } 0.9 \times \frac{\pi}{4} = 67\%$$

In the use of such an amplifier for amplifying modulated high-frequency oscillations this efficiency of 67% will alone occur in a positive modulation peak at 100% modulation of the carrier wave since only in this case the amplitude of the anode alternating voltage is equal to from 0.8 to 0.9 times the anode direct voltage. In the absence of any modulation the amplitude of the anode alternating voltage is only half the said value so that the output does not exceed 33%. For broadcast stations the mean modulation percentage over an entire day is very small because the instantaneous value of the modulation percentage seldom exceeds 30% or in other words the output of a B-amplifier is on the average not much in excess of 33%.

In order to obtain an amplifier having a higher output devices have been suggested in which a load impedance has energy supplied to it by at least two amplifier channels and in which the output circuit of one of these channels is connected to the load impedance over an impedance inverting network, that is to say a network whose input impedance is inversely proportional to the

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terminal impedance of the output circuit. The impedance inverting network may be constituted by a transmission line whose length is a quarter of the wavelength of the oscillations to be amplified. Such amplifiers permit of obtaining an efficiency of about 65% even with low modulation percentage.

The invention has for its object to provide a device for amplifying modulated high-frequency oscillations which has a high efficiency and in which the use of one amplifier channel suffices.

According to the invention, the anode circuit of a high-frequency amplifier valve and a load impedance are interconnected by compound network whose elements are formed by impedance inverting networks, there being arranged at each point of connection between two or more of these networks except at the said anode circuit and load impedance at least one discharge tube which acts as a switch and whose impedance between the anode and the cathode bridges the input or the output circuit respectively of the impedance inverting network at the point of connection, said discharge tube being so controlled that with increasing amplitude of the oscillations to be amplified at least part of these tubes are rendered non-conductive successively and/or alternately so that a stepwise decrease of the input impedance of the compound network is obtained.

According to one embodiment of the invention the compound network may be obtained by connecting each of a group of points over impedance inverting networks to each of a second group of points, the anode circuit of the high-frequency amplifier valve and the load impedance being connected respectively to two of the said points.

The efficiency of a normal B-amplifier is proportional to the amplitude of the oscillations to be amplified. At the maximum value thereof the efficiency is about 67%, at half the value

$$\frac{67}{2} = 33\%$$

and so forth. This is due to the fact that at the highest amplitude of the oscillations to be amplified, the anode voltage of the amplifier valve is controlled completely but at half the value only to the extent of 50% and so forth. The term "complete control" of the anode volt-

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age is used to refer to the condition in which the amplitude of the anode-alternating voltage is a maximum and consequently about 0.9 times the anode direct voltage. The anode load impedance R_a is constant with normal B-amplifiers and is chosen so high that with complete control of the anode voltage, that is to say at the highest value $E_{a \max}$ of the anode alternating voltage E_a the output energy

$$\frac{E_{a \max}^2}{2R_a}$$

is equal to the maximum value of the energy the tube must be capable of supplying.

In the device according to the invention the impedance R_a is not constant but varies stepwise at varying amplitudes of the oscillations to be amplified. At small amplitudes R_a is higher, for example several times higher than would be the case with a corresponding B-amplifier. This results in the anode voltage E_a being completely controlled and the efficiency being high even at a small amplitude. In order that at increasing amplitude of the oscillations to be amplified increase of the output energy may be possible the impedance R_a is decreased discontinuously to a lower amount at which the control of the anode voltage, and thus the efficiency, fall back slightly but the output energy does not vary. At a further increase of the amplitude of the oscillations to be amplified the output energy may therefore again increase until the complete control of the anode voltage E_a is again attained, the impedance R_a being then again reduced discontinuously and so forth. This procedure may be repeated any number of times until the last discontinuity causes the impedance R_a to assume the same value as that which this impedance would possess permanently with the corresponding B-amplifier.

It is obvious that at amplitudes of the oscillations to be amplified between zero and the maximum value the mean efficiency is considerably higher in the method described as compared with a normal B-amplifier.

In order that the invention may be clearly understood and readily carried into effect it will now be described more fully with reference to the accompanying drawings.

The embodiment of the device according to the invention which is illustrated in Fig. 1 comprises a final amplifier valve U of an amplifier for modulated high-frequency oscillations and a load impedance R, which may be for example an antenna, to which the tube U supplies energy.

Between the anode circuit of the valve U and the load impedance R is connected a compound network whose elements are formed by impedance inverting networks $R_0, R_1, R_2, R_3, R_{1'}, R_{2'}, R_{3'}, R_{1''}, R_{2''},$ and $R_{3''}$, which with the exception of R_0 comprise three groups each of which consists of three networks connected in series and thus forming a circuit which is connected in parallel with the network R_0 . At the points of connection between the networks R_1 and R_2, R_2 and $R_3, R_{1'}$ and $R_{2'}$ and so forth are arranged respectively discharge tubes A and B, A' and so forth which act as switches and whose anode circuits are so connected to the networks that the impedances between anode and cathode of the tubes A, B, A' and so forth respectively bridge the input and output circuits respectively of the networks $R_1, R_2, R_{1'}$ and so forth at the points of connection, or in other words at the said points of connection the networks are terminated by the anode-cathode impedances of the tubes A, B,

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A' and so forth. The input impedance of the compound network forms the load impedance R_a of the valve U, the resistance R constituting the terminal impedance of the network. For the sake of simplicity the connection lines between the tubes and networks are shown as single conductors and the sources of supply and control voltages are omitted.

The references $R_0, R_1, R_2, R_{1'}$ and so forth designate impedance inverting networks, that is to say networks having the property that the input impedance is inversely proportional to the terminal impedance of the output circuit and the output impedance is also inversely proportional to the terminal impedance of the input circuit. The product of the input and output impedance respectively and the terminal impedance is constant and it is hereinafter assumed that for the impedance inverting network R_0 and R_1, R_2 and so forth respectively the product of the input impedance and the terminal impedance is equal to R_{02}, R_{12}, R_{22} and so forth respectively. The value R_0, R_1 and so forth is hereinafter referred to as surge impedance. In addition for impedance inverting networks, for example for the network R_0 , the following applies.

$$V = jR_0i$$

in which V designates the voltage across the input terminals of the network R_0 and i the current passing through the terminal impedance of the output circuit. This current is 90° out of phase with the voltage V, is independent of the value of the terminal impedance and at a given surge resistance it consequently only depends on the input voltage V. The same applies to the other networks $R_1, R_2, R_{1'}$, and so forth.

In the device shown in Fig. 1 the discontinuous reduction of the anode load impedance R_a is obtained as follows: It is assumed that the tubes A, B, A' and so forth are so controlled that they are conductive and possess a low impedance between anode and cathode and thus practically bring about a short-circuit of the impedance inverting networks at the points of connection of these networks where the tubes concerned are arranged. The terminal impedances of the networks R_1, R_2 and so forth formed by the tubes A, B, A' and so forth are consequently very low and the input impedances of the impedance inverting networks at the tube U and the resistance R are therefore very high, or in other words the networks $R_1, R_2, R_3, R_{1'}$, and so forth do not allow the passage of current. For the input impedance Z_i of the network R_0 applies:

$$Z_i = \frac{R_0^2}{R}$$

so that under these conditions the load R_a of the tube U is equal to Z_i .

If in a manner hereinafter described the tubes A and B are rendered non-conductive so that the circuit which comprises the networks R_1, R_2 and R_3 starts to allow the passage of current the resulting surge resistance R_{res} of the series combination of the networks R_1, R_2 and R_3 can be derived from the formula

$$R_{res} = -\frac{R_1 R_3}{R_2}$$

R_{res} is therefore negative if one of the magnitudes R_1, R_2 and R_3 or all three are positive. The parallel combination of the network R_0 with

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the circuit R_1 , R_2 and R_3 is equivalent to a network having a surge resistance R_t ,

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_{res}}$$

that is to say that the surge resistances R_0 and R_{res} are in effect connected in parallel. The surge resistance R_t resulting from this parallel combination is smaller than R_0 if R_{res} is positive. Under these conditions the anode load impedance R_a is equal to the input impedance Z_i of the composition of networks R_0 , R_1 , R_2 and R_3 ,

$$Z_i = \frac{R_0^2}{R}$$

being smaller than

$$Z_i = \frac{R_0^2}{R}$$

Due to the tubes A and B being rendered non-conductive the value of R_a is therefore lowered.

A further stepwise reduction of the anode load impedance R_a of the tube U can be obtained if also the tubes A' and B' and then also the tubes A'' and B'' are rendered non-conductive. Fig. 1 shows three circuits of series connected networks obviously this number may be as large as desired.

Referring to Fig. 2, the solid line curve shows the variation of the anode alternating voltage E_a of the tube U in Fig. 1 as a function of the amplitude P of the oscillations to be amplified by the tube. Since the amplification is substantially linear P also represents the amplitude of the current I that passes through the output impedance R_P designates the maximum value of the oscillations to be amplified and of the output current I and P_1 , P_2 and P_3 designate the levels at which the anode load impedance R_a of the tube U is successively reduced discontinuously the dimensions of the impedance inverting networks being assumed to be such that the resulting surge resistance R_{res} of each of the circuits R_1 , R_2 , R_3 , R_1' , R_2' , R_3' and R_1'' , R_2'' , R_3'' is equal to R_0 . The maximum current I passing through the load resistance R, that is to say the current at complete control of the anode voltage of the tube U is therefore increased, each time that one of the circuits R_1 , R_2 , R_3 or R_1' , R_2' , R_3' or R_1'' , R_2'' , R_3'' respectively is added, by the same amount

$$i = \frac{E_{a \max}}{R_0}$$

$E_{a \max}$ designates the amplitude of the anode alternating voltage E_a at complete control. The distances OP_1 , P_1P_2 , P_2P_3 and P_3P_4 along the P-axis all represent this amount

$$i = \frac{E_{a \max}}{R_0}$$

and are therefore shown equal.

The dotted curve of Fig. 2 represents the variation of the anode impedance R_a of the tube U. As explained before, in the amplitude region between O and P_1 in which the network R_0 is alone switched into the circuit this impedance is

$$\frac{R_0^2}{R}$$

In the region between the limits P_1 and P_2 or P_2 and P_3 or P_3 and P_4 respectively, two, three and four circuits respectively with surge resistance

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R_0 are connected in parallel and the anode impedance is

$$\frac{R_0^2}{4R}, \frac{R_0^2}{9R} \text{ and } \frac{R_0^2}{16R}$$

respectively. Fig. 2 shows how at each discontinuity the anode alternating voltage E_a falls back from complete control to a smaller value.

In order to avoid a discontinuity in the output, it is necessary that directly before and after each discontinuous change of the impedance R_a the output energy $I_a 2R_a = I^2 R$ (I_a designating the alternating current component of the anode current of the tube U) should be substantially the same. Since R_a falls discontinuously this is to be taken to mean that I_a must increase discontinuously. If the tube U is a triode an increase of I_a will occur spontaneously but it is possible that without additional means this increase has in fact not the correct value. The distortion that may occur can, however, be neutralized by inverse feedback. If the tubes A, B, A' and so forth are rendered non-conductive in a manner which is to some extent continuous, the distortion to be neutralized by inverse feedback is considerably smaller than would be the case with decisively discontinuous variations.

It is not essential that the resulting surge resistance of the circuits R_1 , R_2 , R_3 , R_1' , R_2' , R_3' and R_1'' , R_2'' , R_3'' should be equal to R_0 , that is to say the amplitude levels from P_1 to P_4 are not necessarily chosen at equal distances. By choosing the level P_1 to be low a higher efficiency is obtained but the amounts by which the impedance successively decreases discontinuously at the levels P_1 , P_2 and P_3 also become greater, and this will result in a greater distortion. The levels P_1 and P_3 are preferably so determined by choice of the networks R_1 , R_2 , R_3 and R_1' , R_2' , R_3' that the amounts by which the anode alternating current I_a must increase each time that one of the circuits R_1 , R_2 , R_3 and so forth is added are equal, the largest discontinuity occurring being in this case a minimum.

It is apparent from the foregoing that the tubes A, B, A' and so forth solely act as switches, that is to say that either they are as conductive as possible or they are entirely non-conductive. The tubes A and B, A' and B' and A'' and B'' respectively are rendered non-conductive on surpassing the amplitude level P_1 , P_2 and P_3 respectively of the oscillations to be amplified, levels at which, as shown in Fig. 2, complete control of the anode voltage E_a of the tube U occurs, and in one form of construction of the device according to the invention this non-conductive condition is obtained due to the fact that a low-frequency voltage that may be obtained after rectification by a device 10 of the oscillations to be amplified and which corresponds with the modulation envelope of the oscillations to be amplified is supplied with negative polarity to a control electrode of the tubes concerned. The tubes are so arranged, for example by means of different grid biases obtained through resistors 11, 12, and 13, that the various sets of tubes, for example the tubes A and B, A' and B' etc. can be rendered non-conductive in succession at the desired amplitude levels of the oscillations to be amplified. For this purpose, the control electrodes of the tubes A and B, A', B' and A'', B'' respectively may be interconnected.

A further modification of the device according to the invention is shown in Fig. 3. In this the

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compound network is obtained due to the fact that between the anode circuit of the tube U and the load impedance R is connected a number of parallel branches (two of which are shown in Fig. 3) each comprising two impedance inverting networks connected in series, designated in Fig. 3 R₁ and R₂, R₁' and R₂' respectively, at the point of connection between which is arranged a discharge tube A, A' respectively that acts as a switch and whose anode-cathode impedance shunts the input and output circuit respectively of the networks concerned at the point of connection. The operation essentially corresponds with that of the device shown in Fig. 1 except that only one branch can be operative at a time so that the branches must be possessed of mutually different surge resistances. The fact that it is impossible for two branches to be connected in parallel may be recognised as follows: For a branch comprising two impedance inverting networks connected in series (for example R₁ and R₂) applies:

$$V_u = \frac{R_2}{R_1} V_i$$

in which V_u designates the voltage across the output terminals of the second network and V_i the voltage between the input terminals of the first network. For the branch which comprises the networks R₃ and R₄ applies:

$$V_u = \frac{R_4}{R_3} V_i$$

If the two branches, that is to say the input and output circuits of the two branches, are connected in parallel the voltages V_u and V_i are equal for the two branches respectively and this is at variance with the two above equations if

$$\frac{R_2}{R_1} \frac{R_4}{R_3}$$

In this case the value V_u=V_i=0 alone satisfies the two equations at the same time, or in other words the two branches are short-circuited on both sides. In the device shown in Fig. 3 connection of two or more branches in parallel is therefore impossible.

A further modification of the device according to the invention is shown in Fig. 4, the anode circuit of the amplifier valve and the load resistance R being connected respectively to two opposite corners of a hexagon whose sides and diagonals are formed by impedance inverting networks from R₁ to R₆. At all corners of the hexagon except at the two mentioned before, is arranged a discharge tube designated A, B, C and D respectively which acts as a switch and shunts the output or input circuit respectively of the networks at the point of connection concerned.

This device permits of obtaining six different values of the anode load impedance R_a of the tube U by the following combination of conductive and non-conductive discharge tubes.

- I—A, B, C, D, non-conductive
- II—A, B, C, D, conductive
- III—A, B conductive, C, D non-conductive
- IV—A, B non-conductive, C, D conductive
- V—A, C conductive, B, D non-conductive
- VI—A, C non-conductive, B, D conductive

By reference to Fig. 4 it can be ascertained that with the combination II the network R₆ is alone switched into circuit, whereas with the other combinations one or more additional circuits formed by series combination of three of the

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other networks are connected in parallel with the network R₆. The tubes from A to D may be rendered non-conductive and again conductive by means of a device comprising a cathode ray tube 14 in which the beam of electrons is deflected under the influence of a low-frequency voltage that may be obtained after rectification of the oscillations to be amplified and corresponds with the modulation envelope of the oscillations to be amplified, the beam of electrons with increasing amplitude of this voltage successively striking a number of electrodes connected respectively to a control electrode of the tubes from A to D in such manner that the tubes from A to D are rendered non-conductive in succession and/or alternately, for example in the order shown by the above table.

If only four of the six possible combinations from I to VI are used, to wit the combinations from III to VI the control of the tubes A, B, C, D can be obtained by simple means. This may be recognised by reference to the following table in which the conditions of the tubes A, B, C, D, (b=non-conductive, c=conductive) are indicated at an amplitude of the oscillations to be amplified which increases from zero to maximum. In this case the networks from R₁ to R₆ should be so proportioned that in the order III, V, IV, VI the combinations made use of lead to a successively lower anode load impedance of the tube U in the manner shown in Fig. 2. The amplitude levels at which a discontinuity in the anode load impedance at the tube U successively occurs are designated P₁, P₂, P₃.

	A	B	C	D
III.....	b	b	c	c
V.....	b	c	b	c
IV.....	c	c	b	b
VI.....	c	b	c	b

small.

—P₁

—P₂

—P₃

large.

amplitude of the oscillations to be amplified.

This table shows that at increasing amplitude of the oscillations to be amplified the tube D or A respectively is rendered non-conductive or conductive respectively at the level P₂, whereas the tube C or B respectively is rendered non-conductive or conductive respectively at the level P₁ and is rendered conductive or non-conductive respectively at the level P₃.

By supplying a low-frequency voltage, which may be obtained after rectification of the oscillations to be amplified and which corresponds with the modulation envelope of the oscillations to be amplified, jointly with suitable bias voltages to a control electrode of the tubes A and D it may be readily ensured that at more negative values than a given instantaneous value of the low-frequency voltage which value corresponds with the level P₂ the tube A is rendered non-conductive and is conductive at positive instantaneous values and the tube D inversely. The desired control of the tubes B and C can be obtained by rectifying the said low-frequency voltage without smoothening and so supplying the direct voltage pulses obtained to the control electrodes of the tubes B and C that at positive or negative instantaneous amplitudes respectively of the low-frequency voltage below a given value corresponding with the level P₃ or P₁ respectively the tube B is conductive and at instantaneous amplitudes above this limit is non-conductive and the tube C conversely.

Fig. 5 shows a further modification of the de-

vice according to the invention which is largely similar to that shown in Fig. 4. In the table below are stated the six serviceable combinations of non-conductive and conductive discharge tubes from A to D.

- I—A non-conductive, B, C and D conductive
- II—B non-conductive, A, C and D conductive
- III—C non-conductive, A, B and D conductive
- IV—B, C and D non-conductive, A conductive
- V—A, C and D non-conductive, B conductive
- VI—A, B and D non-conductive, C conductive

In view of the devices shown in Figs. 3, 4 and 5 it may be remarked that the circuit arrangement of the compound networks used in these devices and built up from the various impedance inverting networks and of further compound networks not described which also may be employed may be obtained by connecting each point of a group of points over impedance inverting networks to each point of a second group of points, two of the said points having respectively connected to them the anode circuit of the high-frequency amplifier valve U and the load impedance R. The other points have connected to them the discharge tubes A, B and C and so forth. This is illustrated by Figs. 6a and 6b in which two groups of points a_1, a_2, a_3 and b_1, b_2, b_3 respectively are connected by straight lines each representing an impedance inverting network. Referring to Fig. 6a, the anode circuit of the tube U is connected to the point a_1 and the load impedance R to the point b_1 . If the other points a_2, a_3, b_2 and b_3 are assumed to be connected to discharge tubes this figure is identical with Fig. 4. Similarly, Fig. 6b is identical with Fig. 5.

Instead of arranging one tube A, B, A' and so forth respectively at the points of connection between the networks, it is possible advantageously to arrange two push-pull connected tubes, no anode voltage being required for the tubes. A suitable arrangement for this is shown in Fig. 7. L_1 and L_2 designate interconnected coils which by means of condensers C_1 and C_2 respectively are tuned to the frequency of the oscillation to be amplified. The anodes of the two pull-push connected discharge tubes A_1 and A_2 are directly connected to the ends of coil L_2 . The control electrodes of the tubes A_1 and A_2 are interconnected and consequently receive the same control voltage. The input terminals k are connected to the input or output terminals respectively of the impedance inverting network at the point of connection between the networks. When the tubes A_1 and A_2 are non-conductive it is easy to ascertain that the impedance between the terminals k has a very low value, whereas the impedance is high when the tubes A_1 and A_2 are conductive.

As mentioned before, the resulting surge resistance R_{res} of the circuits of three series-connected networks, such for example as the circuits R_1, R_2 and R_3 used in the devices shown in Figs. 1 and 4, must be positive; this may be ensured by choosing one of the networks R_1, R_2 or R_3 or all three to be negative, that is to say building them up in such manner that the output current i is -90° out of phase with the voltage V and hence is opposite to that of the network R_0 . A favourable form of construction of these circuits is obtained by using for the network R_2 a filter network which brings about a phase displacement opposite to that of the network R_0, R_1 being equal to $R_2=R_3$. The circuit arrangement of this is shown in Fig. 8a. Due to R_1 being equal to $R_2=R_3$ the inductance L and the capacity C

which are connected in parallel with the tube A and B respectively form an oscillatory circuit which is tuned to the oscillation to be amplified and which has a constant high impedance. This circuit may therefore be omitted so that the simple circuit arrangement shown in Fig. 8b is obtained.

Fig. 9 shows a circuit diagram of the modification of the device according to the invention shown in Fig. 1, the networks from R_1 to R_3 being all chosen to be identical and built up in the manner shown in Fig. 8b.

Instead of using impedance inverting networks built up from concentrated inductances and capacities use may also be made of impedance inverting networks having a distributed inductance and capacity, for example transmission lines having a length equal to an odd number of quarter wavelengths of the oscillations to be amplified. As an alternative, each impedance inverting network may be constituted by itself by an odd number of series-connected impedance inverting networks.

I claim:

1. Apparatus for amplifying amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor the oscillations to be amplified being applied to said grid, a load member, impedance network means arranged to couple the anode circuit of said tube to said member, means to adjust the impedance of said network means in a step-wise manner, the input impedance of said network means forming the anode impedance of said tube and the load member constituting the terminal impedance of said network means, and control means responsive to the varying amplitude of said oscillations and coupled to said impedance adjusting means to adjust the impedance of said network in the inverse direction whereby an increase in the amplitude from a minimum to a maximum value results in a step-wise reduction in the anode impedance of said tube.

2. Apparatus for amplifying amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input impedance of said network forming the anode impedance of said tube and the load member constituting the terminal impedance of said network, said compound network including a single impedance inverting network and a plurality of three series-connected impedance inverting networks all connected in parallel with said single network, a pair of normally closed switching devices for each of said three series-connected impedances, the devices of each pair being bridged across the two junctions in said three series-connected networks, and control means responsive to the varying amplitude of said oscillations for successively actuating each pair of switching devices whereby an increase in the amplitude from a minimum to a maximum value effects a step-wise reduction in the anode impedance of said tube.

3. Apparatus for amplifying in a class B manner amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input impedance of said compound network forming the anode im-

pedance of said tube and the load member constituting the terminal impedance of said compound network, said compound network including a single impedance inverting network and a plurality of three series-connected impedance inverting networks all connected in parallel with said single network, a pair of grid-controlled electron discharge devices for each of said three series-connected impedances, the devices being bridged across the two junctions in said three series-connected networks and being arranged to be normally conductive, and control means responsive to the varying amplitude of said oscillations to apply a voltage to the grids of said discharge devices to successively render each pair of discharge devices non-conductive, whereby an increase in the amplitude from a minimum to a maximum value effects a step-wise reduction in the anode impedance of said tube.

4. Apparatus for amplifying in a class B manner amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input impedance of said compound network forming the anode impedance of said tube and the load member constituting the terminal impedance of said compound network, said compound network including a single impedance inverting network and a plurality of three series-connected impedance inverting networks all connected in parallel with said single network, a pair of normally conductive grid-controlled electron discharge devices for each of said three series-connected impedances, the devices being bridged across the two junctions in said three series-connected networks, grid bias means for said discharge devices, rectifier means for deriving a low frequency control voltage from said tube which varies in accordance with the amplitude of the oscillations therein, and means to apply said control voltage to the control grids of said devices, the biases on the respective control grids of said devices having values at which each pair of said discharge devices is successively rendered non-conductive whereby an increase in the amplitude from a minimum to a maximum value effects a step-wise reduction in the anode impedance of said tube.

5. Apparatus for amplifying in a class B manner amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input impedance of said compound network forming the anode impedance of said tube and the load member constituting the terminal impedance of said compound network, said compound network including a single impedance inverting network and a plurality of three series-connected impedance inverting networks all connected in parallel with said single network, a pair of grid-controlled electron discharge devices for each of said three series connected impedances, the devices being bridged across the two junctions in said three series-connected networks, grid bias means for said discharge devices, rectifier means for deriving a low frequency control voltage from said tube which varies in accordance with the amplitude of the oscillations therein, means to apply said control voltage to the control grids of said devices, the biases on the respective control grids

of said devices having values at which each pair of said discharge devices is successively rendered non-conductive whereby an increase in the amplitude from a minimum to a maximum value effects a step-wise reduction in the anode impedance of said tube, and a negative feedback circuit coupled between the output of said compound network and the grid circuit of said tube and arranged to compensate for distortion introduced by the step-wise variation in said anode impedance.

6. Apparatus for amplifying amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input impedance of said compound network forming the anode impedance of said tube and the load member constituting the terminal impedance of said compound network, said compound network including a single impedance inverting network and a plurality of three series-connected impedance inverting networks all connected in parallel with said single network, a pair of grid-controlled electron discharge devices for each of said three series-connected impedances, the devices being bridged across the two junctions in said three series-connected networks, grid bias means for said discharge devices, rectifier means for deriving a low frequency control voltage from said tube which varies in accordance with the amplitude of the oscillations therein, means to apply said control voltage to the control grids of said devices, the biases on the respective control grids of said devices having values at which each pair of said discharge devices is successively rendered non-conductive whereby an increase in the amplitude from a minimum to a maximum value effects a step-wise reduction in the anode impedance of said tube, a negative feedback circuit coupled between the output of said compound network and the grid circuit of said tube and arranged to compensate for distortion introduced by the step-wise variation in said anode impedance, the surge impedances of the respective networks constituting said compound network having values at which the variation in said anode impedance is effected in uniform steps.

7. Apparatus for amplifying amplitude-modulated high frequency oscillations comprising an electron discharge tube provided with a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input impedance of said network forming the anode impedance of said tube and the load member constituting the terminal impedance of said compound network, said compound network including a plurality of pairs of series-connected impedance inverting networks all connected in parallel, the pairs of said series-connected networks having progressively different surge impedances, a normally closed switching device bridged across the junction in each pair of series-connected networks, and control means responsive to the varying amplitude of the oscillations for successively actuating said devices, only one of said devices being actuated at any one time, whereby an increase in the amplitude from a minimum to a maximum value effects a step-wise reduction in the anode impedance of said tube.

8. Apparatus for amplifying amplitude-modu-

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lated high frequency oscillations comprising an electron discharge tube having a cathode, a grid and an anode and circuits therefor, a load member, a compound network arranged to couple the anode circuit of said tube to said member, the input circuit of said compound network forming the anode impedance of said tube and the load member constituting the terminal impedance of said compound network, said compound network including six serially connected impedance inverting networks arranged to define an hexagon and three impedance inverting networks connected between pairs of opposing vertices of the hexagon one pair of opposing vertices providing the input and output terminals of said compound networks, four grid-controlled electron discharge devices bridged respectively across the remaining vertices of said hexagon, and control means responsive to the varying amplitude of the oscillations to render said electron discharge devices non-conductive in an order effecting a step-wise reduction in the anode impedance as the amplitude goes from a minimum to a maximum value.

9. An arrangement as set forth in claim 8

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wherein said control means comprises rectifier means for deriving a low frequency control voltage from said tube which varies according to the amplitude of said oscillations, a cathode-ray tube having deflecting means and a plurality of electrodes arranged to be scanned successively by the beam, means to apply said control voltage to said deflection means to successively scan said electrodes in accordance with the amplitude thereof, and means connecting said electrodes respectively to the grids of said electron discharge devices.

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