

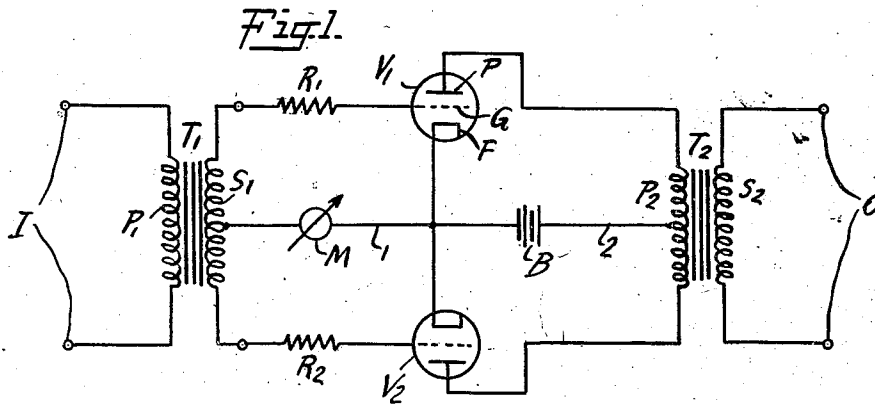
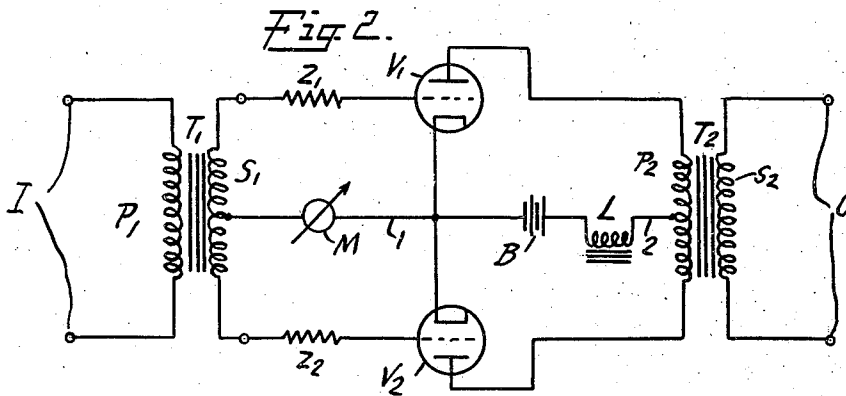
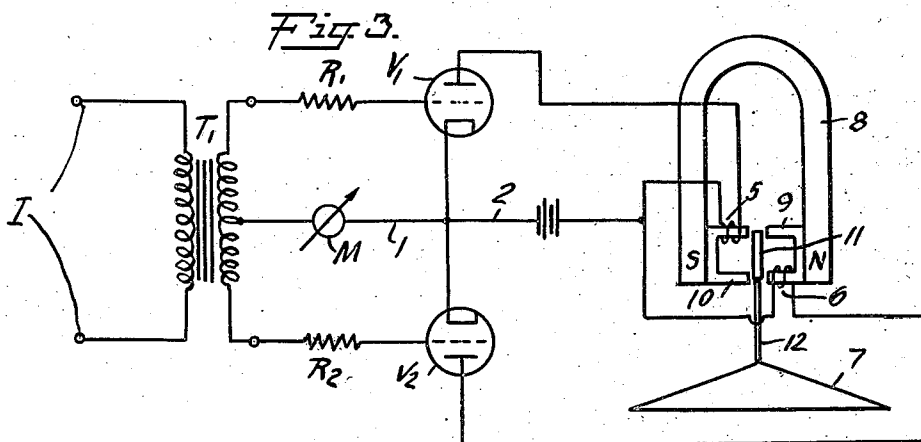
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PUSH-PULL AMPLIFIER

Filed Aug. 17, 1929



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PUSH-PULL AMPLIFIER

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This invention relates to improvements in amplifiers of the low frequency type adapted principally for amplifying currents in the audio frequency range. More particularly, the invention is directed to improvements in thermionic amplifiers operating in so-called push-pull circuits.

An object of the invention is to provide an amplifier of the type mentioned which will furnish substantially distortionless amplification without the necessity for utilizing a biasing battery or an initial negative biasing potential on the control circuits, or grids, of the thermionic tubes.

15 A further object is to provide an amplifier of the type specified adapted to furnish a high degree of substantially distortionless amplification.

20 A further object is to provide an amplifier of the type specified capable of delivering relatively large amounts of distortionless power output.

25 A further object is to provide an amplifier of the type specified wherein the signaling current delivered to the output circuit is caused to flow in series thru the plate circuits of the tubes oppositely connected thereto, such arrangement permitting the most efficient delivery of distortionless power to the output circuit.

30 A further object is to provide a meter in the amplifier circuit which gives a continuous indication of the signal intensity.

35 A further object is to provide an amplifier of the type specified having a relatively low output impedance, as a consequence of utilizing no biasing potential on the grids of the tubes and further as a result thereof requiring a correspondingly lower anode supply voltage than would otherwise be required.

40 As a general proposition, one of the essential requisites to the distortionless amplification of the signaling currents by means of thermionic amplifiers consists in applying to the grids of the thermionic tubes a sufficiently large initial or permanent negative biasing potential to maintain them at all times negative relative to the corresponding cathodes or filaments. For, if the incoming signal wave has a sufficiently great peak value to

carry the grid positive during a portion of each cycle, space current will flow in the grid circuit during such portion thereby causing an increased voltage drop in the input circuit associated with the tube with resultant decrease in voltage impressed between the grid and filament thereof as compared to that of the corresponding negative portion of the signaling wave. As a consequence of this, the amplified signaling wave will contain a flattened portion during each interval that the grid is positive, which effect, of course, is distortion.

It is possible by means of a well designed thermionic amplifier utilizing a sufficiently large permanent negative biasing potential on the grid, to obtain substantially distortionless amplification, but such a result is attained only by sacrificing certain other desirable features. In the first place, the use of the negative biasing potential on the grid of a tube increases the plate circuit impedance thereof by a corresponding amount since the presence of the negative potential on the grid impedes the flow of electrons from the filament to the plate, thus requiring a higher plate circuit voltage for a given plate current. The increased plate voltage required, together with the added grid bias voltage, involves an added expense to the amplifier construction.

In order to partially overcome the above enumerated disadvantages accompanying the use of a permanent negative biasing potential on the grids of the tubes, the so-called "push-pull" amplifier circuit was developed. The push-pull amplifier, as frequently constructed, comprises in essence an input transformer having the secondary winding thereof connected between the respective grids of a pair of similar thermionic tubes, an output transformer having the primary winding thereof connected respectively between the anodes of said tubes, and having the cathodes connected in common to the midpoint of the input transformer secondary winding and also thru a direct plate current supply source to the midpoint of the output transformer primary winding.

If now a sine wave of signaling current is

impressed upon the input transformer of such a push-pull amplifier, there will at each instant of time be signal voltage impressed in a positive sense between grid and filament of one tube and an equal signal voltage impressed in the negative sense between grid and filament of the other tube, and since the voltages thus impressed produce additive effects in the output transformer secondary, it is thus insured that each positive half cycle of amplified signaling current will be identical in wave form with the corresponding negative half cycle. This, however, does not necessarily mean that the amplified wave will be distortionless; it merely means that the even harmonics of the fundamental frequency will be eliminated. The odd harmonics may still be present in sufficient magnitude to cause appreciable distortion.

In addition to the distortion effects noted with the push-pull amplifier as commonly constructed, any grid current in flowing thru the input transformer secondary winding will cause a considerable voltage drop therein which will reduce the net signaling voltage applied between the grid and filament of the tubes and in this way limit the amplification obtainable.

It is proposed in the present invention to improve the push-pull amplifier circuit as commonly arranged in such manner as to substantially eliminate the above noted objectionable effects which result from operating the same without an initial or a permanent negative biasing potential applied to the grids of the vacuum tubes. The improvement is accomplished by serially interposing a high impedance element traversable by direct current, such as an inductance or a resistance, in each lead connecting the grids of the respective tubes to the input transformer secondary. The objects to be accomplished by such modification are to substantially prevent the flow of current in the grid circuits of the tubes and also to prevent the grids being carried positive to an appreciable extent by the applied signaling waves.

Since with the above modification, current flowing in the grid circuit of either tube must traverse the high impedance element connected in the grid lead thereof, such impedance operates automatically to limit the magnitude of current flow. Thus by making the impedances sufficiently high, the grid current flow can be limited to such a degree as to produce negligible distortional or amplification limiting effects upon the amplifier operation.

By making the impedance elements serially connected in the grid leads of large value relative to the operating filament-to-grid resistance of the corresponding tubes, substantially all of the voltage drop due to the flow of grid current will be across the high impedance element and very little across the tube input. This means that the tube will be substantially

inactive while positively biased by the impressed signaling wave, but will strongly repeat the signal while negatively biased thereby since in the latter case the grid to filament impedance amounts to practically an open circuit across which the full signaling voltage is necessarily impressed. Due to the opposite manner in which the tubes are connected to the input circuit, one tube will always be charged negatively by the impressed signaling wave while the other tube is charged positively thereby, with the result that one tube will repeat positive portions and the other negative portions thereof in the output circuit. Further, the negatively charged tube will at each instant be responsible for substantially the entire signal repeated in the output circuit, with the positively charged tube contributing very little. This mode of operation is in contrast with the operation of the push-pull amplifier as commonly constructed wherein the positively charged tube furnished the major portion of the output current.

Due to the fact that with the amplifier as disclosed herein only one tube at a time is active in delivering signaling current, it has been found that the commonly used mode of connecting the output circuit to the amplifier, namely, thru an output transformer having the primary winding tapped at the midpoint and connected thru a B battery to the filament, does not permit the maximum power output from the present circuit. Since only one tube at a time is "active" the output transformer in such case acts as a three-winding transformer having a single primary connected to the active plate, and a pair of windings connected respectively to the plate of the "inactive" tube and to the output circuit. The dynamic plate circuit resistances of both tubes are thus connected effectively in parallel with the output circuit so that the inactive plate acts as a dissipative shunt across the output circuit.

It is well known that in the operation of thermionic tubes the maximum power output consistent with good operation is obtained when the load impedance is substantially greater than the plate resistance. In the above case, the effective load impedance of inactive plate and output circuit in parallel is always less than that of the active plate resistance.

In contrast with the above arrangement wherein the output circuit and the plate circuit resistance are effectively in parallel, it is possible to so arrange the elements that the amplified signaling current flows in series thru the active and inactive plate resistances and thru the output circuit. With such an arrangement the above stated ideal power output condition can be realized to the extent that nearly the entire output from the active tube is delivered to the output circuit and

very little dissipated in the plate resistance of the inactive tube. With such an arrangement a much smaller signal current will flow in the plate circuit of the inactive tube.

One method for obtaining the series arrangement for the output circuit consists in interposing a high impedance traversable by direct current such as a choke coil in the lead containing the B battery supply, which lead, it will be recalled, is connected from the cathodes in common to the midpoint of the output transformer primary. With such an arrangement only the steady direct plate current supply flows thru the high impedance element. Due to the choking action thereof, the major portion of the repeated signaling current is forced to flow in series thru the plate resistances of the active and inactive tubes and thence thru the output circuit.

The series arrangement of the output circuit is inferior to the usual output transformer arrangement of the push-pull amplifier as commonly constructed and using a high initial negative grid bias. The reason is that with such an amplifier both tubes are about equally active at each instant in delivering current to the output circuit and the less active tube is the one with the higher instantaneous plate resistance.

Referring now to the drawing:

Fig. 1 shows in circuit diagram form, an amplifier having the input circuit thereof arranged in accordance with the present invention. The output circuit is shown in accordance with the commonly used construction wherein the plate resistances of the amplifier tubes are effectively in parallel with the output circuit.

Fig. 2 shows a modification of Fig. 1 wherein a "series" arrangement is used for the output circuit.

Fig. 3 shows a modification of Fig. 1 wherein a special type of loud speaker unit is connected directly in the anode circuits of the amplifier tubes with resultant advantages pointed out below.

The expression "divided input section" and "divided output section" as used in the specification and claims denotes the push-pull connection of the amplifier tubes in which the cathodes of the push-pull connected tubes are joined together and connected respectively to an intermediate point of the input circuit and output circuit, while the grids are connected to respective opposite outer terminals of the input circuit and the anodes are connected to opposite outer terminals of the output circuit.

Referring to Fig. 1, the amplifier comprises vacuum tubes V_1 and V_2 , each having grid G, filament F and plate P electrodes. The grids of tubes V_1 and V_2 are connected respectively thru similar resistance elements R_1 and R_2 to the upper and lower terminals of a secondary winding S_1 of transformer T_1 , the primary winding P_1 of which is connected to

a pair of input terminals I. The plates of tubes V_1 and V_2 are connected respectively to the upper and lower terminals of a primary winding P_2 of transformer T_2 , the secondary S_2 of which is connected to a pair of output terminals O. The midpoint of the input transformer secondary S_1 is connected directly to the filament F of tubes V_1 and V_2 thru a milliammeter M by means of lead 1. The meter M is interposed in lead 1 for purposes of continuously indicating the power level of the signaling current. The midpoint of the output transformer primary P_2 is connected by means of lead 2 thru a space supply source B to the filaments of the tubes. The filaments F may be heated in any suitable manner, not shown.

In the operation of the device, when signaling current is so applied to the input terminals I that the lower terminal of winding S_1 is negative relative to the upper terminal, the grid of tube V_2 will be carried negative and that of V_1 positive by the signal voltage induced in the secondary winding. Grid current will flow in the space path of tube V_1 from the filament to the grid of the tube and in series thru the resistance element R_1 and the upper portion of the secondary winding S_1 back to the filament. The resistance R_1 being of large value relative to the filament-to-grid tube resistance, substantially all of the voltage drop due to the grid current will be across the resistance and very little impressed upon the tube input as stated above, causing the tube V_1 to weakly repeat the signal to the output circuit.

On the other hand, since the grid of tube V_2 is carried negative by the signaling wave, the grid circuit of this tube offers practically an infinite impedance connected in series with resistance R_2 across the lower portion of the transformer secondary winding, with the result that the full signaling voltage induced in such portion is impressed between grid and filament of the tube thereby causing the signal to be strongly repeated in the output circuit.

When the impressed signaling voltage is such that the upper terminal of S_1 is negative relative to the lower terminal, the operating conditions will be reversed, the grid of tube V_1 being carried negative and that of tube V_2 positive by the signaling current. Tube V_1 will thus strongly repeat the signal to the output circuit, while the large voltage drop across resistance element R_2 due to the grid current flowing therethru will prevent tube V_2 from being active during such interval as was explained above.

With reference to the output circuit, it is obvious, of course, that during the interval that tube V_2 is active, the signaling energy delivered thereby is dissipated in the output circuit and in the plate circuit resistance of tube V_1 . The output circuit and the plate

circuit of tube V_1 are connected effectively in parallel with the plate circuit of tube V_2 with the resultant disadvantages pointed out above.

Referring now to Fig. 2, the "series" arrangement of the output circuit can be obtained by interposing a high impedance element, such as a choke coil L , in lead 2 containing the source of anode current B . The insertion of this impedance changes essentially the operation of the output circuit from that of the arrangement of Fig. 1.

When no signals are being received, the steady space current supply for tubes V_1 and V_2 flows thru the choke coil L . During reception of a signal, however, the space current will decrease in the plate circuit of the active tube. A very slight corresponding decrease of current thru the inductance element L will set up a choking action which will force substantially all of the amplified signaling current to flow in series thru the plate circuits of the active and inactive tubes and thence thru the entire primary winding P_2 of transformer T_2 .

A choke coil L is preferable for interposition in lead 2 since it offers a relatively low resistance to the space current and hence permits the use of a correspondingly low space supply source B . It will be understood, however, that a resistance element can be used for this purpose or any type of high impedance traversable by uni-directional current.

In Fig. 2 the generalized impedance elements Z_1 and Z_2 replace the corresponding resistance elements R_1 and R_2 of Fig. 1.

The amplifier shown in Fig. 3 is similar to that shown in Fig. 1, with the exception that the anode circuits of tubes V_1 and V_2 contain the voice frequency actuating coils 5 and 6 respectively of a special type of loud speaker, known as a "Farrand inductor dynamic" speaker. This speaker, which is especially adapted for use with the type of amplifier disclosed herein, comprises the coneshaped acoustical diaphragm 7, a permanent horse shoe magnet 8 having affixed to the respective poles thereof, oppositely positioned U shaped pole pieces 9 and 10. The pole pieces 9 and 10 are so dimensioned and positioned as to leave equal air gaps between the opposed legs thereof, in which space an armature 11 is suspended in such manner as to be free to vibrate in a perpendicular direction. A rod 12 connects the lower end of armature 11 to the central point of the cone 7, whereby the cone is vibrated in accordance with vertical movements of the armature.

The coil 5 is placed about the upper leg of pole piece 10 and the coil 6 about the lower leg of pole piece 9. Also coil 5 is connected directly in the plate circuit of tube V_1 , and coil 6 directly in the plate circuit of tube V_2 in such manner that the flux set up by the direct space current in each case aids the flux

of the permanent magnet 8, threading the air gaps between the pole pieces.

The armature 11 has a length about equal to the distance between the centers of the legs of the pole pieces, and is positioned symmetrically within the air gap in such manner as to be pulled equally in opposite vertical directions by the steady flux threading the two air gaps between the pole pieces.

If, now, a signal wave be impressed upon the input terminals of the amplifier, the action of the amplifier is such that the current in signal coil 5 decreases when the grid of tube V_1 is negative, and at the same time the current in signal coil 6 remains constant at the normal direct current value, or increases very little, because the grid of tube V_2 is positive. Likewise, when the grid of tube V_1 is positive, the current in signal coil 5 is practically at the normal direct current value and the current in signal coil 6 is decreased. From the foregoing it is seen that the signal coils are alternately operative and furthermore the coil which is inoperative exerts no influence upon the coil which is operative. This gives the result that the inactive tube of low plate impedance is not effectively a shunt across the output of the active tube, as would be true if a single output transformer were utilized.

The principal advantage of connecting the loud speaker directly in the output circuit is that all frequencies operate on the speaker unit to equal advantage, whereas, if the speaker were connected directly to the terminals of an output transformer, as for example, to terminals O of Fig. 2, the lower frequencies would in general be discriminated against. Another advantage of the arrangement of Fig. 3 lies in the elimination of the output transformer T_2 , which, of course, represents an economy in amplifier construction. The greatest distortionless power output is secured when coils 5 and 6 are practically without mutual magnetic coupling and when the effective impedance of each coil is approximately three times the output impedance of the vacuum tubes individually connected thereto.

Referring back for a moment to Fig. 1, the resistances R_1 and R_2 should be made equal to the corresponding grid to filament resistances of the tubes for amplifying impressed signals of relatively small amplitudes. It has been found that such proportioning of the elements mentioned improves the distortionless amplification obtained. In general a value of .1 megohm for R_1 and R_2 is proper for this purpose.

With the series arrangement for the output circuit as shown in Fig. 2, the circuit has been found to operate most efficiently when the apparent load impedance connected between the anodes of the tubes equals approxi-

mately four times the effective cathode-plate impedance of each tube.

What is claimed is:

1. Electric wave repeating apparatus comprising divided input and divided output circuits with a pair of vacuum tubes connected in opposition therebetween, each of said tubes having a grid and a cathode, said grids being at the same potential as said cathodes in the absence of signaling waves in said input circuit, high resistance means interposed between said grids and said input circuit for rendering one tube unresponsive to positive portions and the other tube unresponsive to negative portions of electric waves in said input circuit.

2. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising divided input and divided output circuits with a pair of vacuum tubes each including grid and cathode connected in opposition between said circuits, resistance means interposed between said grids and said input circuit to substantially prevent the application of a voltage in a positive sense from said cathodes to said grids whereby signal waves present in said input circuit are impressed in substantial entirety upon the tube which receives a negative potential therefrom, whereby said latter tube alone repeats the signal.

3. In an electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, the combination of two repeating elements each comprising a cathode, an anode and an input electrode, the cathodes of both elements being connected together, an input repeating coil the secondary winding of which is connected at an intermediate point to said cathodes and at its opposite terminals to said input electrodes respectively through resistances adapted to cause signaling waves flowing in said coil to be impressed at each instant in substantial entirety upon the element whose input electrode receives a negative potential therefrom, whereby said latter element alone repeats the signal.

4. In an electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, the combination of two repeating elements each comprising a cathode, an anode and an input electrode, the cathodes of both elements being connected together, an input repeating coil the secondary winding of which is connected at an intermediate point to said cathodes and at its opposite terminals thru impedance elements to said input electrodes respectively, whereby signaling waves present in said input coil are impressed in

substantial entirety upon the element whose input electrode receives a negative potential therefrom, whereby said latter element alone repeats the signal, and means connecting said elements in opposition to an output circuit.

5. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising divided input and divided output circuits with a pair of vacuum tubes connected in opposition therebetween, each of said tubes having a cathode, anode and grid, said cathodes being connected together, a resistance interposed between the grid of each said tube and said input circuit, whereby signaling waves present in said input circuit are impressed at each instant in substantial entirety upon the tube whose grid receives a negative potential therefrom, so that said latter tube alone repeats the signal, and impedance means interposed in said output circuit for causing repeated electric waves to flow in series thru the anode resistance of both said tubes and said output circuit.

6. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising a pair of vacuum tubes each having anode, cathode and grid electrodes, a divided input circuit connected at an intermediate point to said cathodes and at opposite outer terminals thru impedances to said grids respectively, whereby signal waves present in said input circuit are impressed in substantial entirety upon the tube whose grid momentarily receives a negative potential therefrom whereby said latter tube alone repeats the signal and a divided output circuit connected at an intermediate point thru an impedance to said cathodes and at opposite outer terminals to said anodes respectively whereby the repeated signal waves are caused to flow in series through said output circuit and the anode-cathode space paths of said tubes.

7. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising a pair of vacuum tubes each having anode, cathode and grid electrodes, an input transformer the secondary winding of which is connected at an intermediate point to said cathodes and at its opposite terminals thru resistances to said grids respectively, whereby signal waves present in said input transformer are impressed in substantial entirety upon the tube whose grid momentarily receives a negative potential therefrom, so that said latter tube alone repeats the signal, and an output transformer the primary winding of which is connected thru an inductance to said cathodes and at its

opposite terminals to said anodes respectively, whereby the repeated signal waves are caused to flow in series through said primary winding and the anode-cathode space paths of said tubes.

8. The combination with a thermionic amplifier for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising a pair of vacuum tubes each having anode, cathode and grid, and a divided input circuit connected at an intermediate point to said cathodes and at opposite outer terminals thru resistances to said grids respectively, whereby signal waves present in said input circuit are impressed in substantial entirety upon the tube whose grid momentarily receives a negative potential therefrom so that said latter tube alone repeats the signal, of a loud speaker unit including means for producing a permanent magnetic flux adapted to maintain in dynamic equilibrium an armature affixed to an acoustical unit, a pair of signal current coils for actuating said armature situated respectively at opposite ends thereof, means so connecting said coils in the anode circuits of said tubes respectively that the fluxes due to the space currents flowing therein in each case aid said permanent flux, whereas signal waves repeated by said tubes produce distortionless resultant actuating effects upon said armature.

9. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising divided input and divided output circuits with a pair of electron discharge devices each including anode, cathode and grid connected in opposition therebetween, and high resistance means interposed between said grids and said input circuit adapted to render at each instant substantially unresponsive to a signaling wave impressed upon said input circuit the said discharge device which receives a positive potential therefrom, whereby signal waves present in said input circuit are impressed in substantial entirety upon the device whose grid momentarily receives a negative potential therefrom, whereby said latter tube alone is effective to repeat the signal.

10. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising divided input and divided output circuits with a pair of electron discharge devices each including anode, cathode and grid connected in opposition therebetween, and resistance of large magnitude relative to the lowest cathode-to-grid resistance of said devices during operation interposed between each said grid and said input

circuit adapted to render at each instant substantially unresponsive to a signaling wave impressed upon said input circuit the said discharge device which receives a positive potential therefrom, whereby signal waves present in said input circuit are impressed in substantial entirety upon the device whose grid momentarily receives a negative potential therefrom whereby said latter tube alone repeats the signal.

11. A thermionic amplifier adapted to provide high degrees of substantially distortionless amplification in the absence of negative biasing potentials in the control circuits of the thermionic elements, comprising divided input and divided output circuits with a pair of thermionic tubes each including anode, cathode and grid connected in opposition therebetween and a resistance of large magnitude relative to the lowest cathode-to-grid resistance of said devices during operation interposed between each grid and said input circuit for causing a signaling wave impressed thereupon to be repeated at each instant in substantial entirety by the said device which receives a negative potential therefrom.

12. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising divided input and divided output circuits with a pair of electron discharge devices each including anode, cathode and grid connected in opposition therebetween, high resistance means interposed between said grids and said input circuit adapted to render at each instant substantially unresponsive to a signaling wave impressed upon said input circuit the discharge device which receives a positive potential therefrom, and addition means associated with said output circuit adapted to cause the repeated signaling wave to flow in series through the anode circuits of both said devices.

13. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising divided input and divided output circuits with a pair of electron discharge devices each including anode, cathode and grid connected in opposition therebetween, a high resistance interposed between each said grid and said input circuit adapted to render at each instant substantially unresponsive to a signaling wave impressed upon said input circuit the discharge device which receives a positive potential therefrom, whereby signals present in said input circuit are repeated only by the device whose grid momentarily receives a negative potential therefrom, and inductive reactance included in the space

current supply circuits of said discharge device adapted to cause the repeated signaling waves to flow in series through the space paths thereof.

5 14. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising in combination a pair of
10 electron discharge devices each having anode, cathode and grid, an input circuit connected at an intermediate point thereof to said cathodes in common and at its opposite terminals to said grids respectively through
15 means adapted to cause a signaling wave impressed upon said input circuit to be repeated at each instant in substantial entirety by the said device which receives a negative potential therefrom.

20 15. Electric wave repeating apparatus for providing a high degree of substantially distortionless amplification in the absence of biasing potentials in the control circuits thereof, comprising in combination a pair of
25 electron discharge devices each having anode, cathode and grid, an input circuit connected at an intermediate point thereof to said cathodes in common and at its opposite terminals to said grids respectively through
30 means adapted to cause a signaling wave impressed upon said input circuit to be repeated at each instant in substantial entirety by the said device which receives a negative potential therefrom, and an output circuit connected at its outer terminals to said anodes
35 respectively and at an intermediate point thereof to said cathodes through space current supply means and an impedance adapted to cause the repeated waves to flow in series through the space paths of both said devices.
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16. The combination with a thermionic amplifier for providing a high degree of substantially distortionless amplification in the
45 absence of biasing potentials in the control circuits thereof, comprising a pair of vacuum tubes each having anode, cathode and grid, and a divided input circuit connected at an intermediate point to said cathodes
50 and at opposite outer terminals through resistances to said grids respectively, whereby signal waves present in said input circuit are impressed in substantial entirety upon the tube whose grid momentarily receives a
55 negative potential therefrom so that said latter tube alone repeats the signal, of a loud speaker unit including means for producing a permanent magnetic flux adapted to maintain in dynamic equilibrium an armature affixed to an acoustical unit, a pair of signal
60 current coils for actuating said armature situated respectively at opposite ends thereof, means so connecting said coils in the anode circuits of said tubes respectively that
65 signal waves repeated by said amplifier tubes

produce additive distortionless resultant effects upon said armature.

17. Electric wave repeating apparatus comprising divided input and divided output circuits with a pair of vacuum tubes each
70 having an anode, cathode and grid, connected in opposition therebetween, said input circuit being connected at an intermediate point to said cathodes in common and at opposite outer terminals through high impedances to
75 said grids respectively, whereby signal waves present in said input circuit are impressed in substantial entirety upon the tube whose grid momentarily receives a negative potential therefrom whereby said latter tube is
80 alone effective to repeat the signal.

In testimony whereof I affix my signature.

HAROLD A. WHEELER.

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