GRID BIAS MODULATED AMPLIFIER

Inventor:
Hans Roder,
by Harry C. Dunkan
His Attorney.
This invention relates to circuits for amplifying and modulating high frequency electric currents.

In television transmission it has been a serious problem to modulate and amplify electric waves over an enormous channel width. The normal channel width for radio broadcast transmission is about 5 or 10 kilocycles, while the carrier and its associated side bands in television transmission may occupy as much as four megacycles. It is an object of my invention to provide improved apparatus which by means of degenerative feedback in a grid modulated stage of amplification provides faithful reproduction over a band width suitable for television transmission or the like.

It is the further object of my invention to provide an improved type of amplifier stage for amplification of television signals which will have no regenerative or degenerative effect upon preceding stages, while it is itself subject to a degenerative feedback voltage. It is also an object of my invention to provide an improved type of amplification by means of electron discharge amplifier devices wherein the devices are biased beyond anode current cut off and wherein degenerative feedback voltage is used with such apparatus.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1, of the drawing illustrates schematically a circuit embodying my invention. Fig. 2 is a somewhat more schematic diagram of the circuit illustrated in Fig. 1; Fig. 3 is a vector diagram supplementing Fig. 2; and Fig. 4 is a modification of the embodiment of Fig. 1, and Fig. 5 represents certain characteristics pertaining to my invention.

In Fig. 1 the primary winding 16 of a coupling transformer 11 is supplied with ultra-high frequency carrier voltage from any suitable source, not shown. A secondary 12 of the coupling transformer 11 is tuned to the operating frequency by a capacitor 13 connected in parallel with the secondary 12. Two electron discharge amplifier devices 14 and 15 are arranged in balanced, or push-pull, relation having their cathodes connected together and to ground. The grids of the devices 14 and 15 are connected by means of capacitors 16 and 17 to the respective ends of the secondary 12 of the coupling transformer 11. The capacitors 16 and 17 are bypassed by suitable grid leaks 18 and 19 respectively, arranged in the conventional manner. A common point in the cathode circuit of the devices 14 and 15 is connected through a source of grid biasing potential 20, and a biasing resistor 21 to the center point 22 of the transformer secondary 12. The grid biasing potential 20 is sufficiently negative to provide class C operation of the amplifier, that is to say that grid current flows in the node circuit of the discharge device only during peaks of the grid voltage. The tuned anode circuit of the apparatus is formed by the inherent capacities of the devices 14 and 15 and by the primary 23 of a coupling transformer 24, the ends of which are connected to the anodes of devices 14 and 15. The center point of the transformer primary 23 is connected through a suitable source of anode potential 25 to a common point on the cathode circuits of devices 14 and 15. The secondary 26 of the transformer 24 may supply modulated high frequency current from the apparatus shown to any desired utilization circuit. A capacitor 27 is connected between the anode of device 14 and that end of the transformer secondary 12, which is connected to device 15. A similar condenser 28 is connected between the anode of device 15 and that end of the transformer secondary 12 which is connected to the grid of device 14. These condensers provide degenerative feedback voltage on the grids of devices 14 and 15, as will be explained below.

An electron discharge amplifier device 29 acts as a modulator and has its anode connected through a coupling capacitor 30 to the center tap 32 of the transformer secondary 12. The cathode may be grounded in the conventional manner and the grid of device 29 supplied with a modulating signal. A suitable source of anode potential for the device 30 is indicated as being supplied to the anode through a resistor 31. Modulating voltage supplied by device 29 will vary the grid bias of devices 14 and 15 and thereby modulate the carrier signals amplified through those devices.

To consider the operation of the electron discharge amplifier circuit shown, let $E_0$ represent the plate voltage and let $E_u$ represent a degenerative feedback voltage which is a definite portion of $E_0$ introduced into the control grid circuit in opposition to the original signal. Let the ratio $E_u/E_0$ be $\frac{1}{2}$.
be represented by \( a \). I have determined that in so far as the control grid circuit is involved, an electron discharge device working into a tuned anode circuit in class C operation appears to be working into a tuned circuit which has twice the value of the anode resistance connected across its terminals. It is known also that if a real resistance be added in parallel to the tuned circuit, the band pass characteristic of the amplifier becomes broader; in other words, by the addition of a resistance in parallel to the tuned anode circuit an electron discharge large amplifier apparatus may be made to have a broader channel width of reproduction. If a sufficiently small resistance be placed in parallel with the tuned anode circuit a sufficiently broad frequency band may be obtained to satisfy fidelity requirements for television transmission. The very serious objection to this procedure is that a large portion of the amplified power is consumed in the resistance. It is possible to avoid placing any resistance in parallel with the tuned anode circuit and at the same time secure the desired wide band characteristic necessary in television applications in accordance with my invention by decreasing the apparent anode resistance of the electron discharge device. This may be conveniently accomplished by introducing a certain amount of degenerative feedback voltage from the anode circuit to the grid circuit of the amplifier.

For example, if a given discharge device having the anode resistance \( R_a \) as determined by the change in anode voltage divided by the change in anode current, be operated class C, as mentioned above, or class B, its anode resistance can be shown to be equal to \( 2R_a \). It can also be shown that, if a degenerative voltage be applied to such a discharge device when operated class B or class C, the anode resistance may be represented by the expression; \( 2R_a/(1 + \mu a) \) in which \( \mu \) is the amplification factor of the discharge device and \( a = E_v/E_a \) as mentioned above. The expression is an exact analysis of class B operation, and a close approximation of class C. The amplification factor \( \mu \) may be of the order of 30 to 50 or greater, and the value of \( a \) may be of the order of \( 10 \) to \( 60 \). Thus the internal resistance of the discharge device operated class B or C, as it appears to the tuned anode circuit may be reduced to 0.5, 0.1, or even less, of the value which it would have were there no degenerative voltage employed. This operates very effectively to increase the bandwidth of the class B or C amplifier, while at the same time it does not increase losses in the circuit or reduce the power capabilities thereof.

Fig. 5 illustrates the improvement in band pass and power handling capabilities of the circuit produced by degeneration. This figure includes three curves A and B showing the relation between power output per tube plotted as ordinates and band width of the tuned amplifier plotted as abscissas. Curve A represents this relation for a class C amplifier operating without degeneration and curve B represents the same relation for the same amplifier operating class C with degeneration in accordance with my invention. It will be seen that for a given band width the power output is greatly increased by the degeneration, or for a given power output the band width is greatly increased.

It is true that by this arrangement somewhat more exciting voltage is required for the grid of the discharge device, but since this can be conveniently obtained and suitable channel width is attainable only with difficulty, this is no disadvantage. In the embodiment shown in the drawing, degenerative feedback voltage is applied to the grids of a circuit which may be a neutralizing bridge. The bridge neutralizes the amplifier in so far as it prevents the effects of any change in the anode circuits of the devices 14 and 15 from appearing at the tuned grid circuit comprising transformer secondary 12 and capacitor 13. That is any transfer of energy between the input and output tuned circuits except through the electronic action of the discharge devices is prevented through neutralization. This bridge circuit, however, does not neutralize insofar as the grids of devices 14 and 15 are concerned, but it actually applies a degenerative feedback voltage thereto. It may be said to compensate for the voltage induced at the ends of the transformer secondary 12 by the inherent capacity between the anodes and grids of devices 14 and 15. In order that this bridge may be effective, it is necessary that it balance. The conditions of balance are fulfilled when the reactance of capacitor 27; the reactance of capacitor 28; the sum of the reactances of capacitor 14 and the capacitance between the anode and grid of device 15; and the sum of the reactances of capacitor 16 and the capacitance between the anode and grid of device 14 are all equal.

In operation, since the bridge is balanced no voltage is fed from the anode circuits of devices 14 and 15 to the tuned grid circuit including transformer secondary 12 and capacitor 13. However, a degenerative feedback voltage is applied to the grids of devices 14 and 15 because their plate-grid capacitance and the capacitances 16 and 17 respectively act as voltage dividers. This action may be best understood by reference to Fig. 2.

In Fig. 2, the elements shown are identical with those in Fig. 1 and have the same numerals. \( E_v \) represents one-half the voltage across the tuned anode circuit. \( C_a \) represents the capacity between anode and grid of device 14 and 15 that is, for device 15. If we consider this bridge representation of the circuit of Fig. 1, when no voltage exists across the tuned grid circuit 14 and 15, \( E_v \) will be distributed across each arm of the bridge. Since the capacitors 16 and 17 are made quite large with respect to the capacity between the grid and the anode of device 14 or device 15, most of the voltage \( E_v \) will be distributed between the anode grid and anode across \( C_a \) and \( C_s \), and only a small fraction will be distributed across capacitors 16 and 17. This is represented in Fig. 3, by the vectors \( E_v \), \( E_a \) and \( E_s \) which are all in phase.

We may now consider the bridge of Fig. 2 in the condition when it has no voltage on its tuned anode circuit, and a voltage \( E_v \) across each half of the tuned grid circuit. This voltage \( E_v \) distributes itself across each arm of the bridge in much the same manner as \( E_a \). As before, the major portion of the voltage exists across \( C_a \) but it exists in phase opposition to the voltage induced thereon by \( E_v \). If now we consider that, due to the voltage \( E_v \), a grid voltage exists represented by vector \( E_{a1} \) with respect to the anode, and, due to the voltage \( E_v \), the grid exists at a voltage \( E_{a2} \) with respect to the filament, the vector sum of these two voltages will be the true grid voltage. As may be seen in Fig. 3, these two voltages \( E_{a1} \) and \( E_{a2} \) are exactly in phase opposition. Hence the voltage \( E_{a2} \) intro-
duced in the grid circuit by means of capacitor 16 from the plate voltage \( E_p \) is a degenerative voltage whose value may be controlled by the ratio between the capacity of capacitor 16 and that between the grid and anode of the device 14. In order that it may be more clearly understood a concrete numerical example of voltage distribution will be set forth wherein the actual grid voltage is calculated and the actual amount of degenerative feedback voltage is determined. Assuming

\[
E_p = 200 \text{ volts}
\]

\[
E_t = 100 \text{ volts, and}
\]

\[
C_1 = 16 \text{ capacity of } C_1
\]

\[
C_4 = 4 \text{ capacity of } C_4
\]

it will be seen that \( E_p \) will appear across \( C_1 \) and \( C_4 \) in the ratio of 160 volts to 40 volts. \( E_t \) being only 100 volts will appear across 16 and \( C_4 \) in the ratio of 20 to 80 volts. Since the point between \( C_1 \) and \( C_4 \), which is at the grid potential is 80 volts away from filament potential due to \( E_p \) and is 40 volts away from filament potential in the opposite direction due to \( E_t \), it will be seen that when both \( E_p \) and \( E_t \) are applied the voltage at this point will become 40 volts, which is the difference between these two vectorial quantities. The voltages given here are purely for purpose of illustration, since in the more usual case the ratio of amplification of the system is far greater than the 2 to 1 ratio above assumed. Similarly, the ratio of the capacitances, or in other words, the amount of degenerative voltage, may be greater than above assumed, as mentioned before.

It is to be understood that the invention described herein may be used in different sorts of apparatus. A slightly different modification is shown in Fig. 4, in which the amplifying circuit uses a single electron discharge device 14. It will be noted that all numerals in Fig. 4 are identical with the numerals in Fig. 1, and are applied to identical parts which perform corresponding functions. The connection to capacitor 30 marked with an arrow is intended as before to be connected to a modulating stage. The capacitor 27 is as before connected between the beginning of the transformer 14 and that of the transformer 12 which is opposite to the end connected to the grid of device 14. By this connection a phase reversal of voltage is obtained to effect neutralization and degeneration. It must be borne in mind that although neutralization is effected at the terminals of the tuned grid circuit 12 and 13, there is an actual degenerative voltage applied to the grid of device 14 due to the voltage drop across the capacitor 16.

The operation of the device illustrated in Fig. 4 is identical with that of Fig. 1, as may be seen from the schematic representation in Fig. 2. If the lower two arms of the bridge and the lower half of the transformer primary 23 be omitted, the schematic diagram of Fig. 2 will represent the embodiment of Fig. 4. It will be seen, therefore, that the operation is identical as the voltage \( E_p \) applied to the transformer primary 23 will be distributed across capacitor 27 in one arm and across capacitor 16 and the anode and grid of device 14 in the other arm as was explained before. Likewise, the grid voltage \( E_t \) will be similarly distributed. In other words, the operation of capacitor 16 in connection with the anode and grid of device 14 will continue to operate as a voltage divider or potentiometer in exactly the same way as in the embodiment of Fig. 1. The vector diagrams of Fig. 3 are valid for Fig. 4.

It is quite obvious that other methods of obtaining neutralizing and degenerative voltage may be employed. In the drawing the invention has illustrated my invention only in a modulated stage which is necessarily operated class C. It may be employed in a subsequent stage to amplify the output from the modulated stage. Such an amplifier is necessarily operated class B, that is, with the grid bias voltage adjusted appropriately to anode current cut off on the absence of a signal. My invention may therefore find wide application in television transmission systems in which single side band transmission now appears to be promising. Such single side band signals may be produced at low energy levels and amplified through class B amplifiers operating with degeneration, in accordance with my invention, to any desired high power level.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereby since different modifications may be made both in the circuit arrangement and instrumentalities employed, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The combination, in a circuit having input and output terminals, and including an electron discharge amplifier device having a cathode, grid, and anode, of compensating means for applying a voltage to said input terminals derived from said output terminals and of such phase and amplitude as to compensate for the voltage induced at said input terminals through the inherent capacity between said anode and grid, and means for supplying a degenerative feedback and voltages from said output terminals to said grid without disturbing said compensating means whereby a wide band amplification characteristic is produced.

2. In combination, an electron discharge amplifier device having cathode, grid, and anode electrodes, an input device having one side connected to said cathode and its other side connected through a condenser to said grid, an output circuit connected between said anode and cathode, whereby the voltage between said anode and cathode is distributed on the elements comprising the capacity between said anode and grid, said condenser, and said input device in series, means to supply from said output circuit to the point between said input device and said condenser a voltage of equal value and opposite phase to the voltage supplied to said point from said output circuit through said discharge device and condenser, the reactance of said condenser being sufficient to maintain on said grid a substantial degenerative alternating voltage, whereby the transfer of energy between said output circuit and input device, except through electronic action in said discharge device, is prevented and the voltage of said condenser produces degeneration in said amplifier.

3. In combination, an input device, an output device, an electron discharge amplifier connected between said input and output devices, said amplifier having an anode, cathode and grid, said input device being connected between said grid and cathode through an impedance and said out-
put device being connected between said anode and cathode, whereby the voltage between said anode and cathode is distributed across the capacitance between said anode and grid, said impedance, and said input device all in series, and means to supply voltage from said output device to said input device to neutralize the voltage supplied thereto through said impedance and capacity, whereby the voltage on said impedance is effective on said grid to produce degeneration in said amplifier.

4. The combination, with an electron discharge device having a cathode, a grid and an anode, an input circuit connected between said grid and cathode, and an output circuit connected between said cathode and anode, of means for supplying a degenerative feedback voltage from said output circuit to said grid, and means for preventing transfer of electrical energy from said output circuit to said grid, and means for supplying to said output circuit a voltage of equal intensity and opposite phase to the voltage supplied thereto from said output circuit.

5. The combination, in an amplifier having an input circuit and a tuned output circuit, of an electron discharge device having a grid, an anode and a cathode, and a condenser connected in series with said grid, cathode and input circuit, the voltage between said anode and cathode being distributed across the capacity between said anode and grid, said input circuit and said condenser all in series, the voltage on said condenser being degenerative and said condenser having such reactance that said voltage on said grid substantially reduces the resistance between the anode and cathode of said device and thereof.

6. The combination, with an electron discharge device having a cathode, a grid and an anode, an input circuit connected between said grid and cathode and a tuned output circuit connected between said cathode and anode, of means for supplying a degenerative feedback voltage from said output circuit to said grid to reduce the resistance between said cathode and anode and produces a wide band pass characteristic through said device, and means for preventing transfer of electrical energy from said circuit to said input circuit, said last means comprising means for supplying to said input circuit a voltage of equal intensity and opposite phase to the voltage supplied thereto from said output circuit through such other paths as exist between said output circuit and said input circuit.

7. The combination, in an amplifier comprising an electron discharge device having an anode, a cathode and a grid, a circuit between said grid and cathode to be supplied with a carrier wave to be modulated, a tuned circuit between said anode and cathode, and means to supply a signal voltage to said amplifier to modulate said carrier wave whereby said carrier wave and modulation side bands appear in said tuned circuit, of means for supplying a degenerative feedback voltage from said tuned circuit to said grid to reduce the resistance between said cathode and anode, thereby to provide more uniform amplification for said side bands, and means for preventing the transfer of electrical energy from said tuned circuit to said first circuit, said last means comprising means for neutralizing in said first circuit the voltage supplied thereto from said tuned circuit, whereby said amplifier has a wide band pass characteristic and voltage in said tuned circuit cannot induce voltage in said first circuit.

HANS RODER.
CERTIFICATE OF CORRECTION.


HANS RODER.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 43, for "bais" read --bias--; page 2, first column, line 71, for "greately" read --greately--; and second column, line 45, for "grid" read --grid--; page 4, first column, lines 37, 38 and 39, for the syllable and words "there- amplifier, by broadens the band pass characteristic of said" read --thereby broadens the band pass characteristic of said amplifier--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 11th day of February, A. D. 1941.

Henry Van Arsdale, 
(Seal) 
Acting Commissioner of Patents.