Dec. 3, 1940. W. E. KIRKPATRICK 2,223,521

HIGH-FREQUENCY SYSTEM

Filed Nov. 11, 1937

FIG. 1

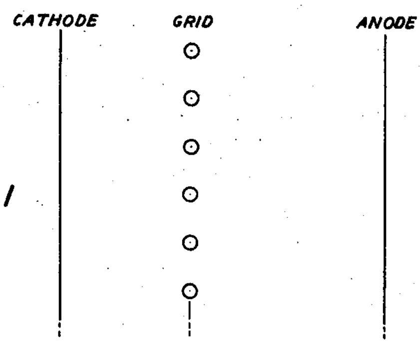


FIG. 2

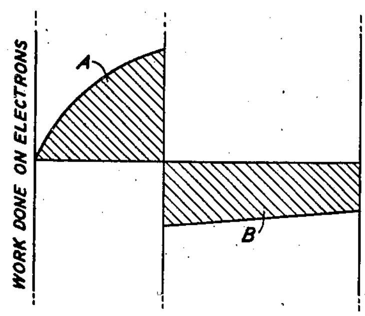


FIG. 3

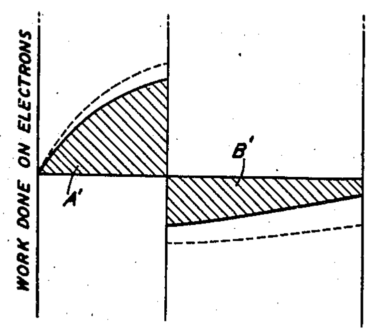


FIG. 4

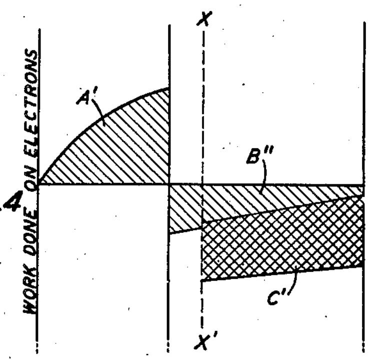


FIG. 5

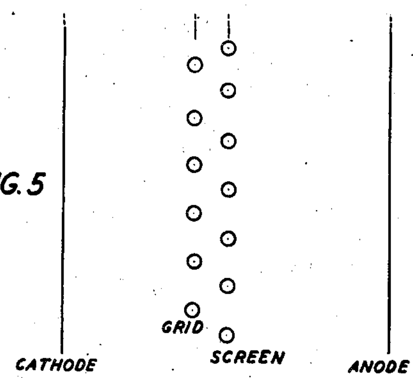


FIG. 6

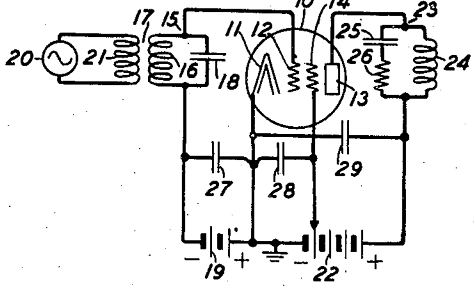
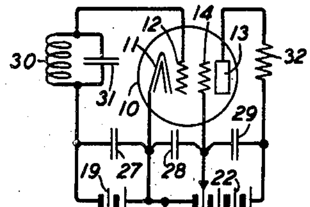


FIG. 7



INVENTOR
W. E. KIRKPATRICK

BY H. A. Burgess

ATTORNEY

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HIGH-FREQUENCY SYSTEM

William E. Kirkpatrick, New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y. a corporation of New York

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13 Claims. (Cl. 179—171)

This invention relates to a high-frequency system, and more particularly, to a method and means for controlling the extent of input or active grid loss in such a system employing an electron discharge device.

It has been found, in the operation of an ultra-high-frequency system employing an electron discharge device comprising a cathode, an anode and a control grid, that, as the frequency or frequencies involved become higher and higher, for example, of the order of 100 megacycles, there is an increasing and a marked input or active grid loss, resulting from a decreasing value of a shunting resistance effectively existing across the input, or in other words, a decreasing value of the input impedance of the device.

An object of this invention is to control the input or active grid loss in an ultra-high-frequency system and either to decrease it, to annul it or to overcompensate for it.

In accordance with this invention, this object is realized by placing an auxiliary electrode or grid between the control grid and anode of the electron discharge device, the auxiliary electrode being capable of secondary electron emission and being maintained at a potential valued to decrease or to annul the input loss at a particular high-frequency or to overcompensate such loss at frequencies lower than some critical frequency.

A more complete understanding of this invention will be obtained from the detailed description which follows hereinafter, taken in conjunction with the appended drawing, wherein:

Figs. 1 to 5 are diagrams to be used in explaining the invention; and

Figs. 6 and 7 show a high-frequency amplifying system and a high-frequency oscillator system, respectively, embodying the means and method of the invention.

Fig. 1 shows the geometrical disposition of the elements of an electron discharge device comprising a cathode, an anode, and a control grid. Let it be assumed that the anode is tied down to the cathode through a large condenser effective at all the frequencies of interest; that the anode is maintained at a fixed potential positive with respect to the cathode, and the grid at a fixed negative potential with respect to the cathode; that a small alternating potential is impressed between grid and cathode, the frequency of this alternating potential being so low that an electron leaving the cathode region at any point of the cycle, reaches the anode before the value of the alternating potential on the grid has changed.

Fig. 2 shows the work done on an electron performing under these conditions on its movement from cathode to anode, released at the instant of maximum positive alternating grid potential. The reversal of sign of the work done on the electron at the instant it passes through the grid plane comes about because the force on the electron caused by the alternating potential is always directed toward the grid while the direction of motion of the electron is always toward the anode. For this low frequency case, the area A is equal to the area B, since the electron rises and falls through an equal potential range.

When the frequency becomes sufficiently high so that the alternating grid potential is no longer constant while an electron passes from cathode to anode, a different situation exists. Consider again the case of an electron released at the instant of maximum positive alternating grid potential. By the time the electron has reached the grid plane, the force due to the grid potential has decreased since the alternating grid potential is no longer at its maximum positive value which existed when the electron was in the cathode region, and the area A′ under the solid line of Fig. 3 indicates the amount of positive work done on the electron. During the passage of the electron from the grid to the anode plane, the alternating grid potential continues to decrease; the area B′ above the solid line of Fig. 3, indicates the amount of negative work done on the electron in this region. The dotted lines show the boundaries of the area A and area B of Fig. 2. Because the alternating potential force has been steadily decreasing while the electron passed from the cathode to the anode, the amount of negative work done on the electron is less than the amount of positive work, and the amount of total work done on the electron, therefore, is positive. This positive work must be supplied at the expense of the alternating current energy. It constitutes the input or active grid loss, the existence of which has been recognized only since the recent advent of ultra-high-frequency. As the input frequency increases, the effective input impedance decreases, and as the frequency employed becomes of the order of magacycles, for example, 100 megacycles, the input impedance becomes so low as to seriously affect the amplification or oscillating characteristics of an ultra-high-frequency system. It is desirable and necessary, therefore, that, in the case of a high-frequency amplifier, this input or active grid loss be effectively reduced or annulled, and in the case of a high-frequency oscillator, be effectively reduced, annulled or over-compensated. Another way of considering it, is that effectively the input impedance must be kept as high as possible, and many times larger than the impedance of the input circuit.

If we consider the work done on an electron leaving at the instant of maximum negative alternating potential, the reverse of the above effect is obtained and the total amount of work done on an electron released at this instant is negative. This negative work yields up energy to the alternating current cycle and tends to build up the alternating current. Fewer electrons, however, are released from the cathode region when the grid is in its negative alternating potential swing than when it is in its positive portion, and the total work done on the electrons for a complete cycle is positive. Analysis of the effect produced by electrons released at other portions of the alternating potential cycle show that the negative and positive amounts of work resulting tend to balance out so that the over-all effect is that noted in the previous statement. A discussion, therefore, only of the effect of the electrons released at the maximum positive alternating grid potential is necessary for this type of analysis since the over-all effect of the operation of the device or tube is the same.

If it were possible to increase suddenly the number of electrons flowing to the anode in the grid-anode region, these electrons would come under the influence of the anode lines of force and join the electrons flowing from the cathode to the anode. These added electrons would yield up their negative or positive energy to the system along with those that originated at the cathode. If there is considered only the short time interval in which electrons released from the cathode region at the moment of maximum positive alternating grid potential flow to and reach the anode, Fig. 4 may be drawn. In that figure, the cross-hatched area C', represents added negative work done because of electrons added at the plane of the screen grid, XX', in a manner to be disclosed presently. Area A' is the same as that of Fig. 3; but area B'' of Fig. 4 is less than area B' of Fig. 3 because some of the electrons that originate at the cathode will be stopped at the screen grid and will not reach the anode, and, hence, cannot contribute to the negative work. The negative work yielded up by the added electrons more than makes up for the slight decrease resulting from the interception of primary electrons.

In accordance with this invention, by the insertion along the XX' plane of Fig. 4 of a screen or auxiliary electrode treated so that one electron impinging on its surface would release several electrons, i. e., a screen having secondary electron emission properties, this effect may be attained. Fig. 5 shows the geometrical disposition of such a screen with reference to the cathode, anode and control grid of a triode. The auxiliary electrode would be maintained at a positive potential with respect to the cathode, but at a lower value than that of the anode, this potential being to attract primary electrons to the screen. The screen could be lined up with the spaces in the control grid so that the primary electrons would be more certain to strike the screen. The secondary electrons released from the screen would find themselves in the field of the stronger force produced by the higher anode potential and would be drawn to the anode, thus producing the increase in negative work indicated by C' in Fig. 4, which results in a reduction in the active grid loss.

The action of the screen in reducing active grid loss may be considered in greater detail. Let it be assumed that the screen grid is tied down to the cathode through a large condenser effective at all the frequencies of interest. The condition of operation of the other electrodes is as noted hereinabove. Let the alternating impulse impressed between the grid and cathode be of high enough frequency to produce active grid loss in the tube. If one starts with zero direct potential applied between cathode and screen grid, and gradually increases the positive direct potential of the screen, then the negative work evidenced by area C' of Fig. 4 will begin to show itself and will increase with the increase in screen potential. Consequently, the active grid loss will start to decrease, and if the negative work evidenced by area C' is made great enough, the active grid loss can be annulled or even overcompensated. Under these conditions, the conventional amplifier, modulator, demodulator, oscillator or any other system depending for its operation on an electron discharge device or tube will be more efficient at ultra-high-frequencies when the secondary emission screen is added.

An ultra-high-frequency amplifier system embodying this invention is shown by Fig. 6. The electron discharge device 10 comprises a cathode 11, for example, of the indirectly heated type, a control grid 12, an anode 13, and an auxiliary electrode or screen grid 14 having secondary electron emission properties for the purpose already pointed out hereinabove. A tuned input circuit 15 comprising the secondary 16 of an input transformer 17 and the shunt condenser 18 are connected in series with grid biasing battery 19 in the grid-cathode circuit. A source 20 of ultra-high-frequency current to be amplified is connected across the primary winding 21 of the transformer 17. The cathode-anode circuit includes anode battery 22 and output network 23 comprising an inductance 24, a condenser 25, and a load resistance 26. The screen grid 14 is connected with the anode battery so that it has an adjusted direct potential applied to it that is less than that of the anode. By-pass condensers 27, 28 and 29 are connected between the grid and cathode, cathode and screen grid, and cathode and anode.

In operation, ultra-high-frequencies, which may be of the order, for example, of 80–100 megacycles, originate in the source 20 and are impressed on the grid-cathode circuit through the input transformer and tuned circuit 15. As explained hereinabove, if the device 10 were a triode there would be active grid loss because of the variation in grid alternating potential during the transit of an electron or electrons from the cathode 11 to the anode 13. Because of the presence of the screen grid 14, whose potential has been adjusted to a value such that sufficient secondary electrons are added to those passing from the cathode to the anode, the active grid loss is annulled or compensated and the device functions as if there were no input or active grid loss. The amplified signal is produced in the output network 23, and may be picked off across the resistance 26.

Considered from another viewpoint, if the device 10 were a triode, at ultra-high-frequencies its input impedance would become quite low in relation to the impedance of the input circuit. By utilizing the disclosed auxiliary electrode arrangement, the input impedance of the device is effectively increased to many times the value of the input circuit impedance, and for all practical purposes to an infinite value. There will be, therefore, no effective low shunting resistance across the input circuit, and the active grid loss will be minimized to the extent determined by the direct potential on the auxiliary electrode.

An ultra-high-frequency oscillator system is shown by Fig. 7, elements of which correspond to those of Fig. 6 having like identifying characters. Inductance 30 and condenser 31 comprise a tuned circuit across which oscillations will appear when the combined area of B'' and C' (Fig. 4) is made greater than that of A'. Under such conditions, the effective resistance of the device is negative and oscillations will build up until the positive resistance caused by the circuit losses balances the negative resistance. The oscillations may be picked off across load resistance 32.

In the discussion with reference to Figs. 4 and 5, it was noted that the cathode, screen and anode were connected together for alternating current. In actual operation, the electrons that go to the screen produce no high-frequency energy in the anode circuit and so cause a reduction in the efficiency of the system. Enough electrons must go to the screen to produce the secondary emission required to reduce, annul or overcompensate for the active grid loss; therefore, the shielding action of the screen, consequent to its area and direct potential, should not be so large as to prevent an over-all gain in the number of electrons in the control grid-anode region that finally reach the anode over the number existing in the cathode-control grid space.

Although this invention has been disclosed with reference to certain specific embodiments, it is to be understood that it is not limited thereto, but only by the scope of appended claims.

What is claimed is:

1. In a high-frequency system, electron discharge means comprising a cathode, an anode and a control electrode, said electrode being biased to a potential negative with respect to said cathode, an input circuit and an output circuit for said means, said means having active grid loss, and an auxiliary electrode providing secondary electron emission for controlling the extent of the active grid loss, said auxiliary electrode being maintained at a potential with respect to said cathode less positive than said anode, and adding electrons to those flowing from said cathode to said anode.

2. In a high-frequency amplifier, an electron discharge device comprising a cathode, an anode, a control electrode and an auxiliary electrode, said anode and auxiliary electrode being maintained at potentials positive and said control electrode being biased to a potential negative with respect to said cathode, and an input circuit and an output circuit for said device, said auxiliary electrode providing secondary electron emission whereby the active grid loss that would be present in the absence of such secondary emission is substantially reduced, the potential of said auxiliary electrode being such that an increase thereof increases the number of secondary electrons emitted therefrom, and a decrease thereof decreases the number of secondary electrons emitted therefrom.

3. The method of controlling the active grid loss in electron discharge means comprising a cathode, an anode and a control electrode, that comprises providing secondary electron emission in said tube from a source other than said cathode, anode and control electrode, to reduce, annul or overcompensate for such active grid loss.

4. In an ultra-high-frequency system, an electron discharge device comprising a cathode, an anode and a control grid, an input circuit, the input impedance of said device at ultra-high-frequencies being low because of active grid loss, and an auxiliary electrode in said device for effectively increasing said input impedance to a higher value at such frequencies by reducing the active grid loss, said auxiliary electrode having a secondary electron emission property.

5. An ultra-high-frequency system comprising an electron discharge device, an input circuit and an output circuit for said device, said device having a cathode, an anode, a control grid and a screen grid, said screen grid being treated to emit a number of secondary electrons for each electron flowing from said cathode to said anode that strikes the screen grid, to add such secondary electrons to the primary electrons flowing to said anode, and being maintained at a potential such that the effective input impedance of the device is many times larger than the input circuit impedance.

6. In electron discharge means comprising a cathode, an anode and an input control electrode and whose input impedance tends to become effectively smaller as the frequency of the input signal thereto increases until at or above a particular frequency the discharge means becomes substantially inoperative, the method of compensating for this tendency which comprises providing secondary electron emission in said tube from a source other than said cathode, anode and input control electrode, to reduce, annul or overcompensate for such tendency.

7. In a high-frequency system, electron discharge means comprising a cathode, an input control grid, an anode, and an auxiliary grid between said input grid and said anode, and having secondary electron emission property, and means for impressing across the cathode-input grid an input wave of a frequency of the order of tens of megacycles per second, the effect of active grid loss resulting from said high-frequency input being reduced by secondary emission from said auxiliary electrode.

8. In a high-frequency system, electron discharge means comprising a cathode, an input control grid, an anode, and an auxiliary grid having secondary electron emitting property, an input circuit comprising said cathode and input grid, an output circuit comprising said cathode and anode, and means for impressing an input wave of a frequency of the order of tens of megacycles per second on said input circuit only, active grid loss resulting from such high-frequency input being reduced by secondary electron emission from said auxiliary electrode.

9. In a high-frequency system, electron discharge means comprising a cathode, an input control grid, an anode, and an auxiliary grid having secondary electron emitting property, said auxiliary grid being positioned between said input grid and said anode, an input circuit comprising said cathode and input grid, an output circuit comprising said cathode and anode, and means for impressing an input wave of a high-frequency on said input circuit, active grid loss

resulting from said high-frequency input being reduced by secondary electron emission from said auxiliary electrode.

10. The method of operating an electron discharge device comprising an electron emitting cathode, an anode, a grid, and a discharge controlling member to translate a high-frequency electric wave, which consists in applying a constant positive potential to said anode; applying to the grid a positive potential of such value that primary electrons from said cathode cause secondary electrons to be given off from the grid, and such that the number of secondary electrons given off will decrease if the potential of the grid is decreased and increase if the grid potential is increased; varying the potential of the discharge controlling member in accordance with the electric wave; and producing an emission of secondary electrons from said grid to increase the number of electrons flowing to said anode during a complete cycle of the electric wave over the number that would flow to the anode in the absence of said grid.

11. In a high-frequency system, an electron discharge device comprising a source of primary electrons, an input control grid biased to a potential negative with respect to the primary electron source, a second grid constituting a source of secondary electrons, and an anode, the second grid being located between the input grid and the anode, means for impressing across said primary electron source and said input grid an electric wave of such high frequency that the effective input impedance of said device in the absence of said second grid would be reduced to a value comparable to or less than that of the input circuit impedance, said second grid being maintained at such a positive potential with respect to said primary-electrons source and having such electron emissivity as to enable an over-all gain in the number of electrons in the input grid-anode region that finally reach the anode over the number existing in the cathode-input grid space.

12. An electron discharge system comprising a source of primary electrons, an anode, an input control grid between said electron source and anode, means impressing across said electrons-source and grid an electric wave of such high frequency that the alternating grid potential does not remain constant while an electron passes from said source to the anode, whereby the total work done on the primary electrons for a complete cycle of the wave is positive, and means comprising a source of electrons to be added to the primary electrons flowing to said anode to increase the amount of negative work done on the electrons in the system whereby the total work done on the electrons in the system for a complete cycle of the input wave is less positive than if said electron-adding means were omitted.

13. An electron discharge system comprising a source of primary electrons, an anode, an input control grid biased to a potential negative with respect to said electrons-source and positioned between said source and said anode, means impressing across said source and said grid an electric wave of such high frequency that the alternating grid potential does not remain constant while an electron passes from said source to said anode, whereby the total work done on the primary electrons for a complete cycle of the input wave is positive, and means comprising a second grid having a surface treated to emit secondary electrons when said primary electrons impinge thereon and positioned between said input grid and said anode, said second grid being at a potential positive with respect to said primary-electrons source but less than the positive potential of said anode, said secondary electrons being added to the primary electrons passing to the anode to increase the amount of negative work done on the electrons in said system so that the total work done on the electrons in said system for a complete cycle of the input wave is less positive than if said second grid were omitted.

WILLIAM E. KIRKPATRICK.