Dec. 24, 1940. R. L. SNYDER 2,226,077

RADIO FREQUENCY MULTIPLIER AMPLIFIER

Filed Nov. 29, 1937

Fig. 1.

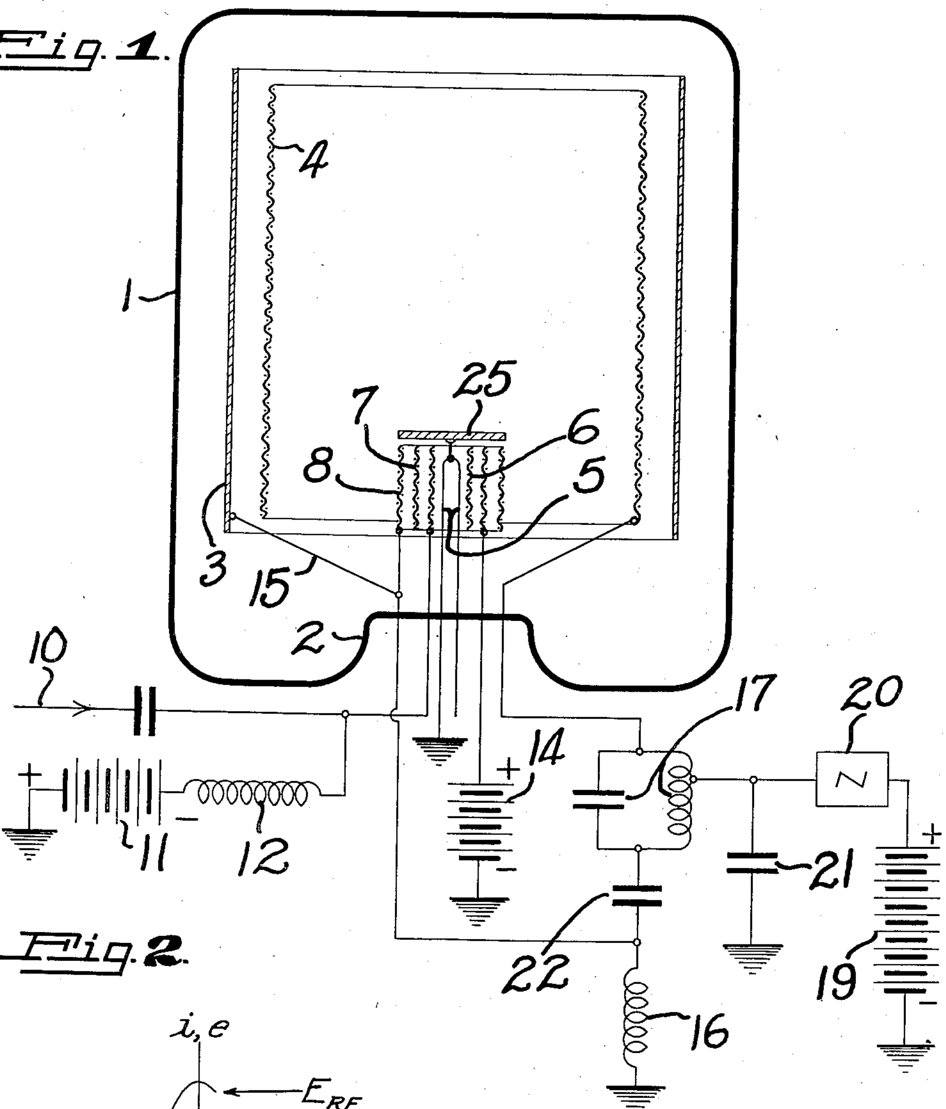
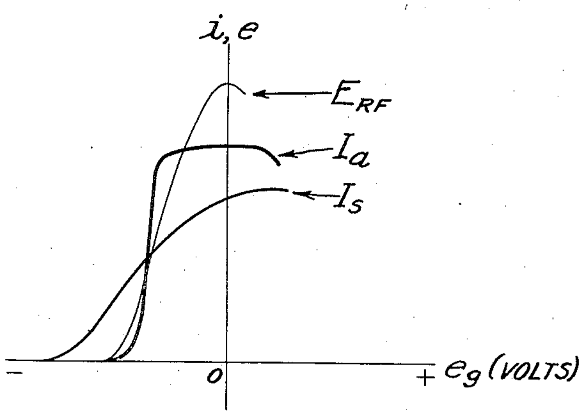


Fig. 2.



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RADIO FREQUENCY MULTIPLIER AMPLIFIER

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Application November 29, 1937, Serial No. 177,066

5 Claims. (Cl. 179—171)

My invention relates to electron multiplier tubes, and more particularly to an electron multiplier tube which can be used as an amplifier.

Among the objects of my invention are:

To provide an electron multiplier tube which will act as an amplifier of frequencies differing from the multiplier frequency; to provide a method of operating an electron multiplier tube, whereby the alternating exciting voltage is modulated, this exciting voltage controlling the amount of current multiplication in the tube; to provide, in a single tube, multiplication of relatively low frequency input giving the same frequency output, but wherein the amplification is obtained by alternating current multiplication by secondary emission; to provide a relatively low frequency amplifier utilizing a relatively high frequency electron multiplier; to provide a single tube which will amplify relatively low frequencies, the tube being the source of self-excited relatively high frequency alternations which create current multiplication of the relatively low frequency input; and to provide a simple and efficient method of utilizing secondary emission to create relatively low frequency amplification.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments utilizing the method, within the scope of the appended claims.

In the following specification, the term relatively low frequency shall be deemed to include the input frequency it is desired to amplify, and the term relatively high frequency shall be deemed to include the higher frequency which is utilized to create the amplification by electron multiplication the lower frequency may be up to and approaching one-half the higher frequency.

Referring to the drawing:

Figure 1 is a longitudinal sectional view of one preferred form of amplifier tube embodying my invention, together with an attached diagram of one particular circuit for accomplishing my method.

Figure 2 is a graph showing certain characteristic curves common to such tubes, as exemplified by Figure 1.

Referring directly to the drawing for a description of the apparatus involved, an envelope 1 is provided at one end with a reentrant stem 2 supporting the entire structure. The details of support are not shown, inasmuch as there are innumerable ways of supporting the structures shown within the tube, all well known to those skilled in the art.

First within the envelope, nearest the wall thereof, is a multiplier cathode 3, cylindrical in form, preferably imperforate and sensitized to produce secondary electrons at a ratio greater than unity upon electron impact therewith. The only surface necessary or sensitization is, of course, the inner surface of this cylinder. The multiplier cathode may be sensitized in many different ways, such as forming the cylinder of silver, oxidizing the silver, and applying caesium vapor to the oxidized silver in manners well known in the art, and in this manner secondary emission may be obtained in ratios as great as ten or twelve to one.

Immediately inside the multiplier cathode 3 is a multiplier anode screen 4, highly permeable to electrons, and these two structures together constitute the high frequency multiplier system of the tube. At one end of the multiplier structure is an input structure and comprising an axially located thermionic emitter 5 surrounded by an input grid 6, the input grid surrounded by a concentric screen grid 7 and by an accelerating electrode 8. The input structure corresponds closely to the well-known thermionic type of a tetrode tube where the accelerating electrode 8 would be replaced by an imperforate anode. In the present case, however, the accelerating electrode 8 is highly permeable to electrons, so that most of the electrons from filament 5 will pass therethrough in order to impact multiplier cathode 3 after passing through multiplier anode 4.

In the circuit shown, filament 5 is grounded and an audio-frequency input applied to the control grid 6 through input lead 10. This control grid may be biased in any convenient manner by bias source 11 through bias inductor 12, if the input frequency is high, or if the input frequency is low, bias inductor 12 may be a bias resistor. The screen grid 7 is placed at a positive potential to cathode 5 by screen source 14, accelerating electrode 8 is connected to the multiplier cathode 3 by an inner link 15, and the two structures on the outside of the tube are grounded through choke 16. Multiplier anode 4 and multiplier cathode 3 are connected together through a multiplier resonant circuit 17, and the multiplier anode 4 is held at a positive potential to multiplier cathode 3 by multiplier source 19 through a load 20 across which the amplified signal may be taken off.

I prefer to use a high frequency by-pass 21 across load 20 and source 19, and place a blocking capacity 22 between multiplier anode and cathode in series with resonant circuit 17. It will be seen that multiplier cathode 3 and multiplier anode 4, being connected through a resonant circuit 17, and having a source of positive potential for anode 4, form a structure and circuit which is a self-oscillator, broadly in accordance with the teachings of Philo T. Farnsworth, as set forth in application Serial No. 61,042, filed January 27, 1936, since matured into United States Patent No. 2,137,528, dated November 22, 1938.

Electron multipliers of the type described in the patent just referred to comprise a cylindrical grid serving as an anode and an electron collector surrounded by a concentric cylindrical cathode, the inner surface of which is sensitized for secondary-electron emission. The anode and cathode are usually connected to each other by way of a source of unidirectional current in series relation with a tuned resonant circuit. In this circuit connection, tubes of the type described generate oscillations. In a preferred mode of operation, the resonant circuit is tuned to a period which is substantially longer, preferably of the order of ten times longer, than the transit time of the electrons diametrically across the tube structure. Electron multiplication takes place during one-half of the cycle of the resonant frequency by repeated impact of the electrons upon the cathode, while electron collection takes place during the remaining half cycle. In case a thermionic cathode is employed to supply a primary flow of electrons which is modulated in accordance with an input signal, the amplitude of the oscillations generated by the tube varies in accordance with the amplitude of the input signal.

In operation, an input signal is applied to the control grid 6 of the input structure, and in order to prevent the multiplier fields from affecting the operation of the input structure, I prefer to shield the top of the input structure by shield plate 25, extending across the entire top of the input system and attached to cathode 5. The input signal controls the emission from the filament 5, and the electron stream passes through the screen grid 7 and through the accelerating electrode 8 into the high frequency multiplier space to impact the lower portion of multiplier cathode 3.

The resonant circuit 17 between the multiplier anode and cathode may be tuned to a frequency approximately equal to that corresponding to the transit time of the electrons between impacts on multiplier cathode 3 but is preferably tuned to a frequency of the order of ten times lower than that corresponding to the transit time of the electrons, as mentioned before. As the high-frequency multiplication starts, there will be a varying potential applied to the accelerating electrode 8, since this electrode is connected to the multiplier cathode 3. Thus, the electron stream coming from the input cathode will be continuously modulated by the radio-frequency voltage, as determined by the resonant circuit 17.

Referring more in detail to the operation of the device, a flow of primary electrons is emitted by the thermionic cathode 5 and controlled in accordance with an input signal applied to the control grid 6 by way of a coupling condenser, a suitable bias being provided for the control grid by the battery 11 in cooperation with the inductance element 12.

The screen grid 7 is held at a positive unidirectional potential of about 50 volts with respect to the cathode 5 by means of battery 14 and has the usual well-known function. The electron flow emitted by the cathode 5, and modulated by the input signal applied to the control electrode 6, is directed against the inner surface of the cathode 3 which it impacts with sufficient velocity to liberate secondary electrons. The secondary electrons are accelerated, due to the positive potential of the anode 4 in the unidirectional space enclosed by the anode, traverse and leave the same to strike another portion of the secondary-electron emissive surface of cathode 3. The secondary electrons liberated thereby are again accelerated by the anode 4, traverse the space of the same and impact another portion of cathode 3. This process repeats itself over one-half cycle of the oscillating potential generated in the tuned resonant circuit 17. During the subsequent half cycle of the oscillations, the electrons still traverse the space enclosed by the anode 4. However, they no longer can impact the cathode 3 since its potential continuously becomes more negative. The electrons are thereby gradually decelerated and collected by the anode 4. This mode of operation is described in detail in the United States patent above-referred to. A portion of the oscillating potential generated in the resonant circuit 17 is also applied to the accelerating electrode 8 and modulates the electron flow, already modulated by the input signal, in accordance therewith. Thus, the electron flow emanating from the accelerating electrode 8 and flowing toward the cathode 3 is modulated in accordance with the input signal as well as in accordance with the oscillations. The amplitude of these oscillations, however, is controlled by the amount of current flow in the tube and thus by the input signal. Since the envelope of the oscillations and the input signal are of the same phase, there is developed a regenerative action which substantially increases the mutual conductance of the tube.

Since it is well known that the unidirectional plate current component of an electronic oscillator increases with increasing amplitude of oscillation, the magnitude of unidirectional current flow through the load 20 fluctuates in accordance with the envelope of the oscillations developed in the resonant circuit 17, which, in turn, is controlled by the input signal. Hence, if the load 20 is represented by an ohmic resistor, a voltage drop is developed thereacross which is of identical wave shape as the input signal but of amplified magnitude.

Figure 2 shows a set of curves for the operation of the device. The curve labeled I_s is the current in the screen grid for varying voltages of the control grid. The curve labeled E_{RF} shows the radio-frequency voltage across the resonant circuit 17 as a function of the control grid voltage. It may be seen from this curve that the amplitude of high frequency voltage obtained is a function of the control grid voltage. The curve marked I_a shows the current in the load as a function of the control grid voltage, and the difference in slope between the screen grid current I_s and the load current I_a clearly shows the increase in mutual conductance obtained.

I claim:

1. A signal translating device comprising means for producing a primary flow of electrons, means

for modulating the intensity of said electron flow in accordance with an input signal, means for multiplying said modulated electron flow by secondary emission, means for utilizing said multiplied electron flow to generate electrical oscillations, means for controlling said primary electron flow in accordance with said oscillations, and means for developing an output signal in accordance with fluctuations in the amplitude of said oscillations.

2. A signal translating device comprising means for producing a primary flow of electrons, means for modulating the intensity of said electron flow in accordance with an input signal, means including an oscillatory circuit for multiplying said modulated electron flow, means for controlling said primary flow of electrons in accordance with the oscillations developed in said oscillatory circuit, and means for developing an output signal in accordance with fluctuations in the amplitude of said oscillations.

3. A signal translating device comprising means for producing a primary flow of electrons, means for modulating the intensity of said electron flow in accordance with an input signal, means comprising a cathode and an anode for multiplying said modulated electron flow by secondary emission, an oscillatory circuit connected between said anode and said cathode, means for applying an operating potential to said anode, means for controlling said primary flow of electrons in accordance with the oscillations developed in said oscillatory circuit, and means for developing an output signal in accordance with fluctuations in the amplitude of said oscillations.

4. A signal translating device comprising means for producing a primary flow of electrons, means for modulating the intensity of said electron flow in accordance with an input signal, means comprising a cathode and an anode for multiplying said modulated electron flow by secondary emission, an oscillatory circuit connected between said anode and said cathode, means for controlling said primary flow of electrons in accordance with the oscillations developed in said oscillatory circuit, means for supplying a unidirectional operating current to said anode, and means for utilizing the fluctuations in said operating current to develop an output signal.

5. A method of signal translation which comprises producing a primary flow of electrons, modulating the intensity of said electron flow in accordance with an input signal, multiplying said modulated electron flow by secondary emission, utilizing said multiplied electron flow to generate electrical oscillations, controlling said primary electron flow in accordance with said oscillations, and developing an output signal in accordance with fluctuations in the amplitude of said oscillations.

RICHARD L. SNYDER