Sept. 26, 1939. P. T. FARNSWORTH 2,174,488

OSCILLATOR

Original Filed March 12, 1935

Fig. 1.

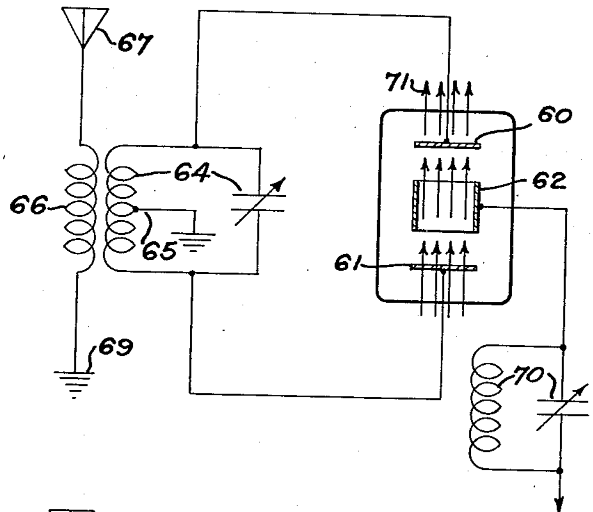


Fig. 3.

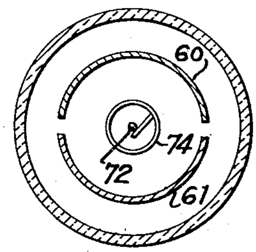


Fig. 2.

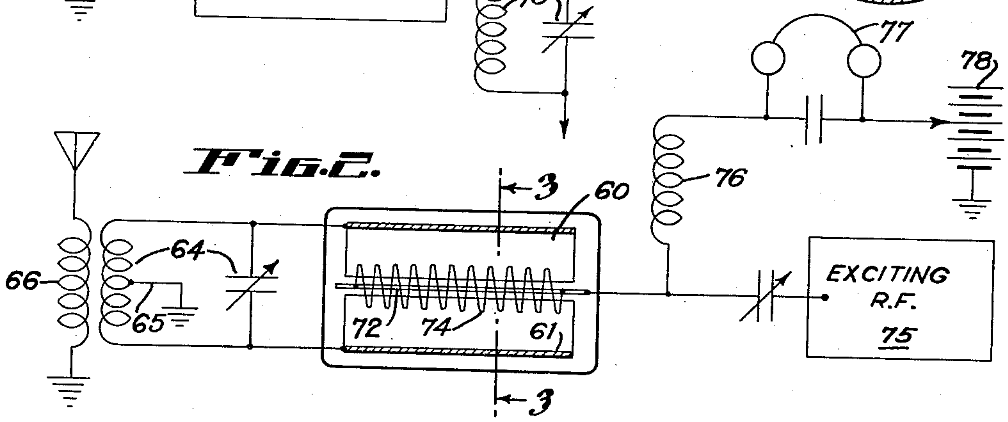


Fig. 4.

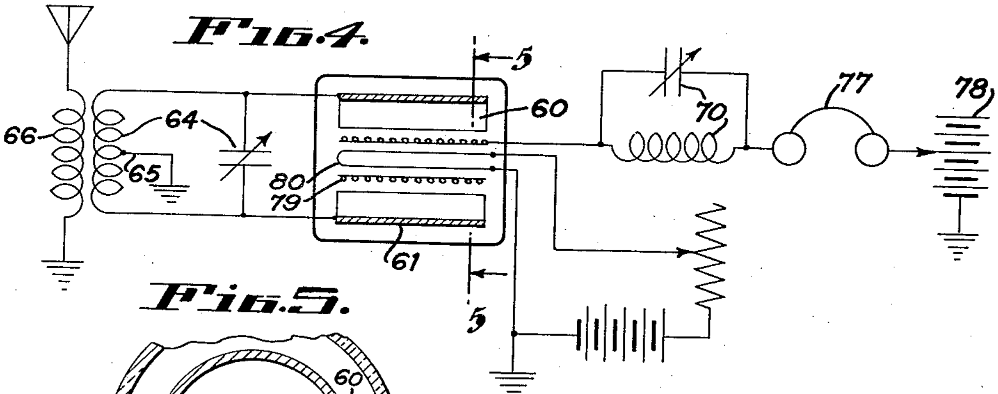
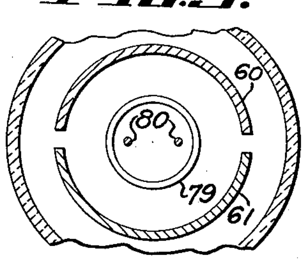


Fig. 5.



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UNITED STATES PATENT OFFICE

2,174,488

OSCILLATOR

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Original application March 12, 1935, Serial No. 10,604, now Patent No. 2,143,262, dated January 10, 1939. Divided and this application April 26, 1937, Serial No. 138,922

5 Claims. (Cl. 250—27)

This application is a division of my application entitled "Means and method for interrupting electron multiplication", Serial No. 10,604, filed March 12, 1935, Patent No. 2,143,262, dated January 10, 1939.

My invention relates to electron multipliers, namely, to means and method for causing small space currents to liberate large numbers of additional electrons to permit relatively large proportional space current to flow, and particularly, it relates to a means and method for removing certain limitations in the operation of electron multipliers, disclosed and claimed in my copending application, Serial No. 692,585, filed October 7, 1933, Patent No. 2,071,515, dated February 23, 1937, of which the present application is a continuation in part.

In the application above cited, the theory and practical aspects of electron multiplication by secondary emission are discussed, pointing out therein that certain limitations in the maximum multiplication obtainable could be overcome by interrupting the action periodically. It is with this phase of electron multiplication that the present application deals, together with the circuits and preferred embodiments of the apparatus for that purpose.

Among the objects of my invention are: To provide means for causing a small number of electrons to initiate a relatively large proportional electron flow; to provide a television image dissector of greatly increased sensitivity; to provide a space charge device of novel type having characteristics adapted for use as a multiplier of electronic currents and preferred circuits for so operating the device; to provide a simple and efficient radio receiving device; to provide a multiplier operating intermittently; to provide current multiplication of a high degree; to provide an electron multiplier and circuit therefor adapted for high output currents; to provide a means and method of obtaining electron multiplications of exceptionally high values; to provide an electron multiplier of exceptionally small size having high current outputs; to provide an electron multiplier operating without an external focusing field; to provide an electron multiplier which is self-interrupting in its action; to provide a means and method for interrupting the action periodically of an electron multiplier in order to remove factors limiting multiplication; and to provide a new and novel method of operating electron multipliers.

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.

Referring to the drawing:

Figure 1 is a circuit showing an embodiment of my invention as applied to radio receiving.

Figure 2 is a circuit diagram showing another form of multiplier connected in a circuit where the action is periodically interrupted.

Figure 3 is a sectional view taken as indicated by the line 3—3 in Figure 2.

Figure 4 is a circuital diagram of another embodiment of my invention as applied to radio receiving.

Figure 5 is a partial sectional view of the multiplier used in Figure 4, taken as indicated by the line 5—5 in Figure 4.

In the figures, circuits are shown whereby an electron multiplier is used for detection of radio frequency signals. It will be noticed that in all of these three circuits, the radio frequency, presumably modulated or keyed in accordance with signals, is the sole energization of the cathodes. In other words, a multiplier tube such as has been described, is used without any R. F. excitation of the cathodes except the signal. The amount of signal necessary to operate a tube in this manner depends primarily on how sensitive the cathode surfaces are and how efficient the transfer of electron energy through the circuit is. As the efficiency of these two factors is increased, the tube's sensitivity increases until finally it will become a good self-oscillator. Tubes, however, which will not self-oscillate in a circuit as shown, for example, in Figure 1, where the cathodes are energized solely by an incoming R. F. signal train, work well as a detector with a signal of the order of .1 volt or less.

For example, if the device is to be used as a straight multiplier, it may be constructed with a pair of opposing cathodes 60 and 61 with a ring anode 62 positioned between them. A tuned circuit 64, comprising an inductance and capacity has its opposite ends connected to the cathodes and its mid-point 65 grounded. The tuned circuit is fed from a primary inductance 66 which may be in the output of a radio frequency amplifier, or connected directly to an antenna system comprising an aerial 67 and a ground 69 or equivalent collector. If, then, the ring anode 62 were to be energized directly from an anode battery, for example, at a voltage of 70 volts, the R. F. voltage across the cathodes would be tremendously increased due to the multiplication created by the electrons within the tube, oscillated under the influence of the applied R. F. voltage. The time of flight within the tube may be conveniently adjusted by varying the voltage of the anode battery for the particular wavelength being received, so that the time of flight corresponds at least in some degree to the incoming frequencies. The device operating under these conditions is of course supplied with its original electrons either by beginning the multiplication with a free electron existing in space between the two cathodes or by the release of electrons due to impact upon the cathode of a metallic ion such as caesium ion, providing the cathodes are sensitized with caesium.

When an electron multiplier is utilized in this manner, however, amplification factors of 20 to 100 can be obtained, further gains being terminated by the limiting effects above referred to. I, therefore, prefer to interrupt the anode supply at an intermediate frequency, preferably 2×10^6 cycles when 50 to 150 megacycles are being received. The interrupting frequency is controlled by the tuned circuit 70 connected to the anode and fed at the desired frequency by any suitable oscillator. Inasmuch as the multiplier tube illustrated in Figure 1 is provided with parallel planar plates, it is desirable to place the tube under the influence of an external magnetic field as indicated by arrows 71 in order that the multiplying action may be efficient.

By the use of the interrupting intermediate frequency, much larger gains may be obtained in the output of the multiplier and it can be readily seen by those skilled in the art that the receiving circuit of Figure 1 will be suitable for use with a steady anode supply under certain circumstances, and suitable for other uses with an interrupted anode supply as shown in the drawing, the tube operating in both cases in identical manner as regards the energization of the cathodes directly from the incoming signal.

It should also be pointed out that when an interrupted anode supply is used that the detected component may be obtained directly from the anode circuit or the output may be taken off at the interrupting frequency if it is desirable to further amplify with an intermediate frequency amplifier. Thus, the multiplier device connected as shown in Figure 1 may be used as a primary oscillator, or at least a device acting as a frequency converter, where intermediate frequency amplification might appear desirable.

The same results can be obtained with a detector circuit as shown in Figure 2. Here signal energy contained in the primary 66 of the R. F. transformer is transferred to the tuned circuit 64 having its midpoint 65 grounded, and this energy is then led to the cathodes and is the sole source of potential for these cathodes. The anode in this case is preferably an axial rod 72 having wound around it and connected thereto a fairly wide mesh grid 74. In this case, no external field is necessary for focusing the electrons because the two plates are semi-cylindrical and the static field created by their opposition is sufficient to prevent immediate collection. I use the anode with a grid connected to it in order that the probability of collection may be increased. In other words, electrons entering the space bounded by the grid wires will be more probably collected due to the shielding action of the grid.

It is of course obvious that electrons passing through short chords of the grid space will not be collected, while those passing through longer chords approaching the diameter will be collected. By shaping the cathodes, I am able to decrease the probability of collection because of the shaping of the electrostatic field therebetween and by putting a grid around the anode I am able to increase the probability of collection, both the increase and decrease of probability by the two methods being independent of one another. Thus, I am able to regulate the probability, for example, of collection without interfering with the static field and I am able to change the static field and compensate therefor by the use of the grid to obtain certain desired results.

The circuit as shown in Figure 2 is adapted to be used as an oscillating detector and I have therefore shown a source of exciting R. F. 75 for the anode 72—74. This excitation is not necessary, however, in case the multiplier tube associated with the circuit is a self-oscillator. In other words, if the multiplier is sufficiently sensitive to generate self-oscillations, the R. F. is unnecessary. Therefore, the multiplier shown in Figure 2 is not only a very good regenerative detector, either with or without an exciting source, according to its sensitivity, but is also capable of being operated as a super-regenerative detector interrupting itself at a frequency which will be determined by an inductance 76 placed in series with an output device 77 and the variable source 78, the latter being variable in order to regulate the time of flight in accordance with the incoming signal. Whether or not there is an exciting R. F. supplied to the tube, I prefer to have the device oscillated at 60 to 100 megacycles for a signal frequency of 30 to 60 megacycles, these adjustments, however, being all within the skill of those familiar with the art.

This particular arrangement is extremely sensitive and a satisfactory detector. Its high sensitivity is obtainable without critical adjustment. Here again, the detected component may be obtained directly from the anode circuit, or the output may be used to supply an intermediate frequency amplifier. The interrupting action produced by the resonant circuit in series with the anode is obtainable either on the portion of the multiplier characteristic showing a negative resistance or at a difference of frequency between the electron period and the signal frequency, or at a difference of frequency between the exciting R. F. and the signal frequency, as may be desired.

It is also possible and sometimes preferable to build the multiplier as a photo-ionic tube duplicating the action of the tube shown in Figure 2. Such a tube and circuit is shown in Figure 4. In this combination the interrupting action is obtained by beat between the signal frequency and the electron frequency. Here, again, the cathodes are supplied solely by the signal circuit 66—64, while the anode in this case is preferably a relatively close meshed grid 79. Inside the grid is positioned a heated filament 80 which is, however, not adapted to provide electrons by emission therefrom, but is purely a source of light so that the photosensitive cathodes may be initially energized to emit photoelectrons. This is operable because practically all surfaces readily emitting secondaries upon impact are also photosensitive. In this way, the number of trips necessary to build up the multiplier current is reduced. The tuned circuit **70** is attached as usual in the anode circuit comprising the output device **77** and the anode supply **78**, and an oscillator may be coupled thereto to provide interruption.

I have thus provided a means and method whereby the output of a multiplier tube may be greatly increased by the removal of certain limiting factors; principally by interrupting the action of the multiplier. The multiplier may be either an oscillating or a non-oscillating condition. It may be supplied with a varying source of electrons, with a steady source of electrons, or with no source at all, reliance being placed in the latter case on casual electrons present. I may prefer to deliberately interrupt the action or to so connect the tube that it will interrupt itself. The latter condition can be accomplished when the tube is sufficiently sensitive to be a self-oscillator. I have shown that either the cathode energization or the anode potential may be interrupted. I have shown that tubes interrupted in this manner may be used to multiply an extraneous source of electrons varying in number, or I may utilize the interrupting action to facilitate the use of the tube as a detector, the output of the detector being available both as a detected component, or as an intermediate frequency carrying the signal impulses. And I have further shown that the multipliers may be used without any external guiding field and when used as a detector may have the cathodes energized solely by a modulated R. F. preferably one which is derived from space.

I have further shown that I may regulate the probability of collection in two manners: (1) by the regulation of the fields through which the electrons travel, due to the arrangement of the cathodes, or an external field; or (2) I may place means around the anode in order to provide a substantially equipotential space of relatively large diameter around the anode without substantial mechanical obstruction to the flight of electrons.

I claim:

1. In means for electron multiplication having a pair of opposed surfaces, and means for energizing said surfaces alternately to produce periodic electron bombardment of said surfaces at a velocity sufficient to create secondaries upon impact, a relatively small collecting electrode between said surfaces, means for energizing said collecting electrode to cause collection of electrons, and conductive means adjacent said collecting electrode to increase the probability of collection without substantial physical interference with oscillating electrons.

2. In means for electron multiplication having a pair of opposed surfaces, and means for energizing said surfaces alternately to produce periodic electron bombardment of said surfaces at a velocity sufficient to create secondaries upon impact, a collecting electrode between said surfaces, means for energizing said collecting electrode to cause collection of electrons, and a grid wound around and connected to said collecting electrode to increase the probability of collection.

3. In means for electron multiplication having a pair of opposed surfaces, and means for energizing said surfaces alternately to produce periodic electron bombardment of said surfaces at a velocity sufficient to create secondaries upon impact, a collecting electrode between said surfaces, means for energizing said collecting electrode to cause collection of electrons, and means adjacent said collecting electrode to increase the probability of collection with minimum physical obstruction to electrons not collected.

4. In means for electron multiplication having a pair of opposed surfaces, and means for energizing said surfaces alternately to produce periodic electron bombardment of said surfaces at a velocity sufficient to create secondaries upon impact, a collecting electrode between said surfaces, means for energizing said collecting electrode to cause collection of electrons, and conductive means for creating a substantially equipotential space surrounding said collecting electrode.

5. In means for electron multiplication having a pair of opposed surfaces, and means for energizing said surfaces alternately to produce periodic electron bombardment of said surfaces at a velocity sufficient to create secondaries upon impact, a collecting electrode between said surfaces, means for energizing said collecting electrode to cause collection of electrons, and means for creating a substantially equipotential space surrounding said collecting electrode at collecting electrode potential.

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