Feb. 24, 1942. P. T. FARNSWORTH 2,274,194

APPARATUS FOR AND METHOD OF ELECTRON DISCHARGE CONTROL

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FIG. 1

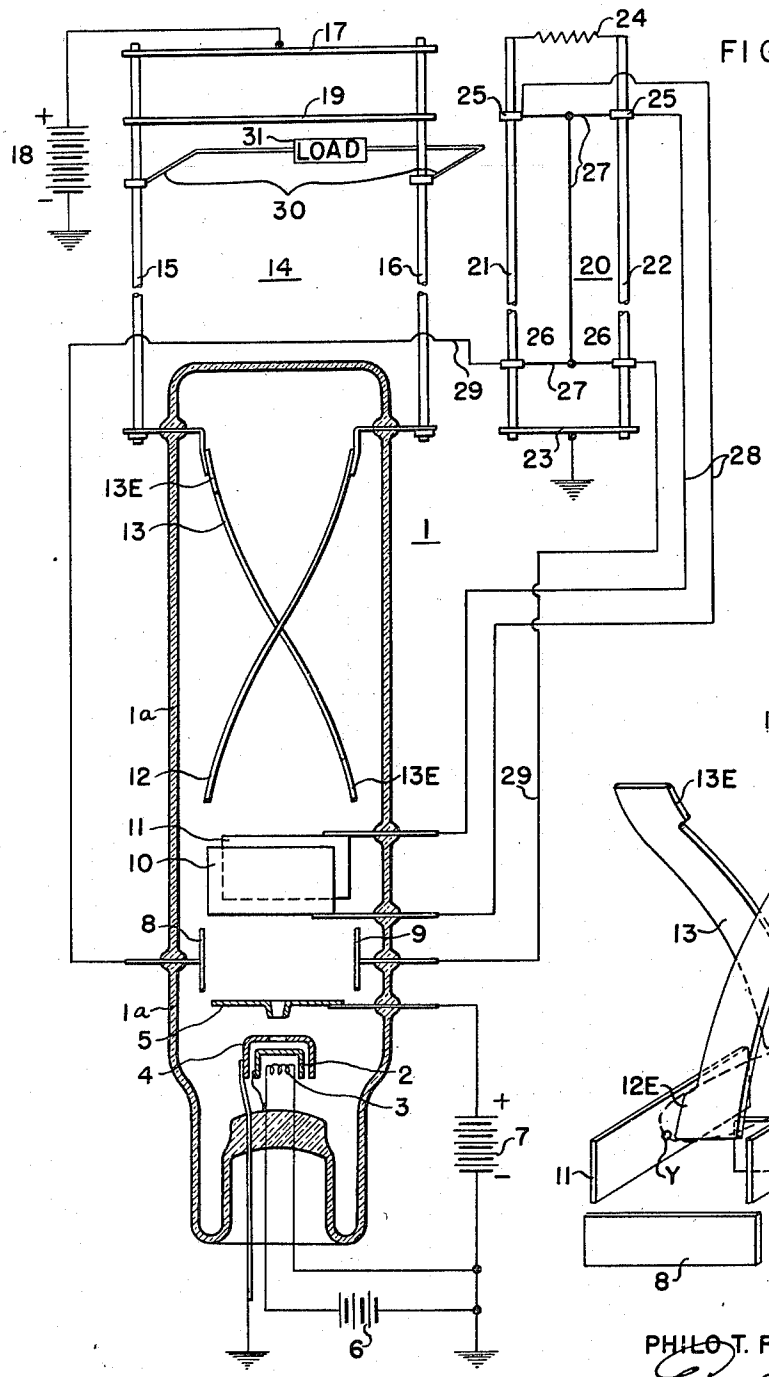


FIG. 2

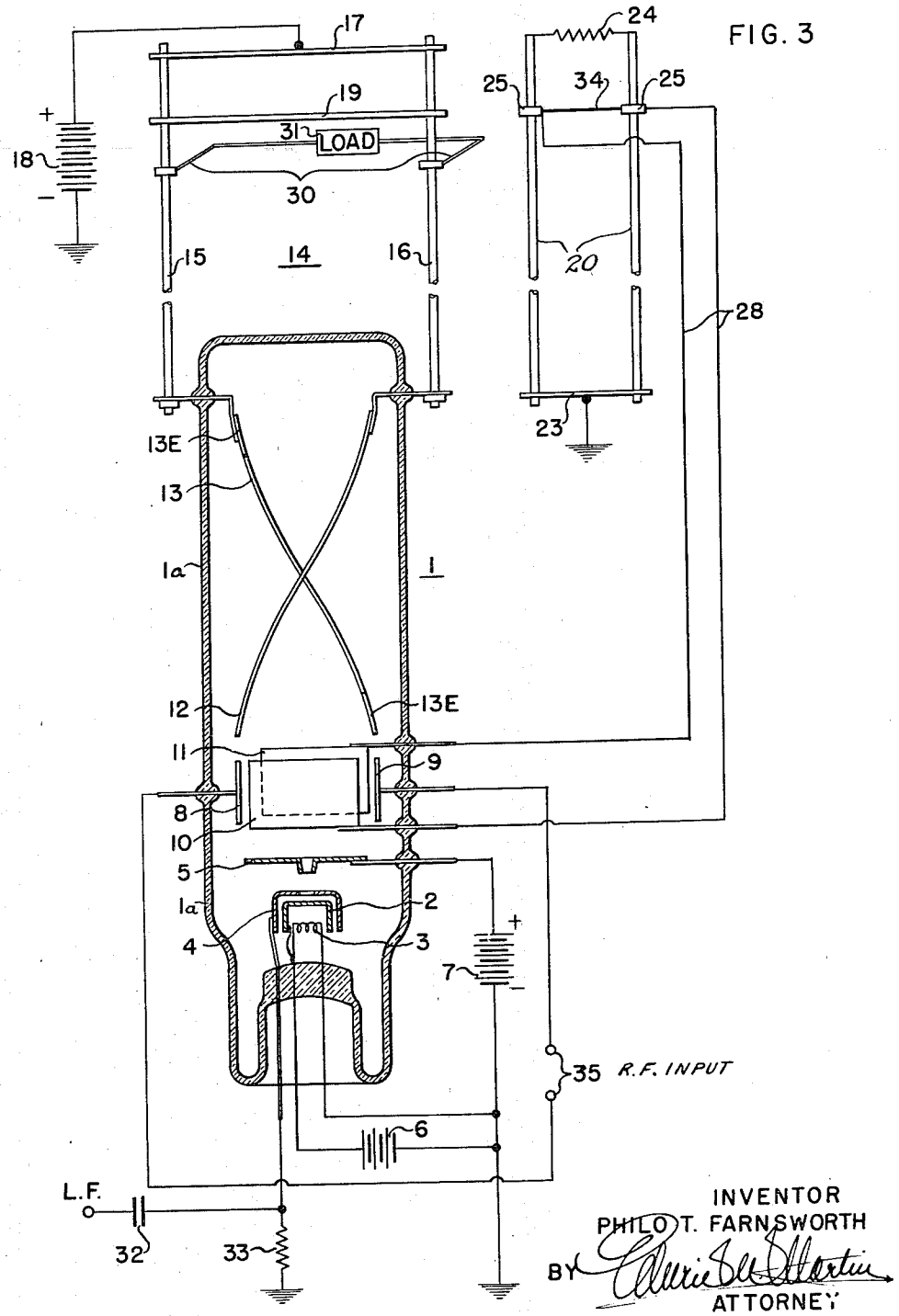
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APPARATUS FOR AND METHOD OF ELECTRON DISCHARGE CONTROL

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FIG. 3



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APPARATUS FOR AND METHOD OF ELECTRON DISCHARGE CONTROL

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Application February 23, 1940, Serial No. 320,449

13 Claims. (Cl. 250—27)

This invention relates to a method of and means for controlling electrons, and more particularly to electron discharge tube arrangements.

Heretofore, electron discharge tubes utilized for the amplification of radio frequency signals at high power have been operated as class C amplifiers which are conductive only during a short interval of the cycle of the radio frequency signal when the effective anode voltage is at its lowest value. If, for example, the interval of conductivity of such a tube is equal to 10% of the radio frequency cycle, the average plate current is at most 10% of the available cathode emission and, since the cathode must be heated constantly, approximately 90% of the cathode heating power is not utilized in the development of the anode current. This is extremely inefficient since substantial power is required for heating the cathode of tubes of this type. Moreover, when utilizing only 10% of the available cathode emission, the power developed in the anode circuit of such an amplifier tube is only 1% of the power which theoretically could be realized by utilizing the entire available cathode emission over the entire cycle of the radio frequency signal.

It is an object of the persent invention to provide an improved method of and means for controlling electrons with relatively high efficiency.

In accordance with the present invention there is provided a method of and means for electron control whereby electrons are generated and are directed into space. The electrons emitted during predetermined time intervals are cyclically and substantially simultaneously collected at the points in this space which they have reached at the end of each of the time intervals to develop a signal.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings Fig. 1 is a schematic diagram of a vacuum tube and a circuit therefor embodying the present invention and arranged for use as an oscillation generator; Fig. 2 is a perspective view of the electron beam targets and the beam deflecting plates of the tube of Fig. 1; and Fig. 3 is a schematic diagram of a vacuum tube and a circuit therefor embodying the present invention and arranged for use as a modulator.

Referring now more particularly to Fig. 1 of the drawings, there is here shown schematically an oscillation generator constructed in accordance with the present invention. A vacuum tube 1, having an evacuated envelope 1a, is provided at one end with an electron gun of conventional construction, positioned coaxially with the axis of the envelope and comprising a cathode 2, indirectly heated by a heater element 3, a control element 4, and an anode 5, as shown, adapted to cooperate to produce a beam of electrons of defined cross-section. The heater 3 is connected to a suitable source of current as, for example, battery 6, one terminal of which is preferably grounded as shown. The anode 5 is connected to a source of constant voltage as represented by battery 7. The control element 4 is preferably connected to ground, as shown, although, if desired, it may be biased to any suitable potential necessary to adjust the proper amount of electron current, as well understood in the art. A pair of parallel deflecting plates 8 and 9 are mounted on opposite sides of the axis of the tube, and a second pair of parallel deflecting plates 10 and 11 are mounted in planes normal to those of the plates 8 and 9 also on opposite sides of the axis of the tube, as shown. The assembly of deflecting plates being positioned coaxially with the electron gun structure is adapted to effect movement of the electron beam in two directions in accordance with signals applied to the plates as will be presently explained.

Targets 12 and 13, shown in detail in Fig. 2, preferably formed of flat strips extending in S-curved planes crossing each other as well as the axis of the envelope, are positioned between the deflecting plates 8—11 and the end of the envelope remote from the electron gun. The two targets are separated from each other and are provided at both ends with portions 12E and 13E extending toward and through a central plane between the targets, so that an overlap in space is obtained at each end of the target assembly.

The circuit in the arrangement of Fig. 1 comprises a transmission line 14 including two parallel conductors 15 and 16 connected to the targets 12 and 13 respectively. A crossbar 17 connects the ends of the conductors 15 and 16 remote from the targets and is preferably connected to the positive terminal of a voltage supply source such as, for example, battery 18. A conductive arm 19 is slidably connected to the conductors 15 and 16 and is so adjusted as to make

the effective length of the transmission line equal to one-quarter of the wave length of the radio frequency signals to be amplified.

Coupled to the transmission line 14 is a second transmission line 20, comprising conductors 21 and 22 connected at one end by an arm 23 which is grounded, as shown, and having their opposite ends terminated with a resistor 24 having a value equal to that of the characteristic impedance of the line. The line 20 is provided with two pairs of sliding contacts 25, 25 and 26, 26 which are effectively spaced a quarter-wave length apart by means of an insulating member 27. Contacts 25, 25 are connected to the deflecting plates 10 and 11 by way of suitable leads 28, 28, while contacts 26, 26 are connected with the deflecting plates 8 and 9 by way of suitable leads 29, 29, as shown.

In Fig. 2 the assembly of the deflecting plates 8, 9, 10 and 11 and the targets 12 and 13 is shown in perspective. The dotted line A indicates the path of the electron beam when deflected by potentials applied to the deflecting plates.

Referring now to the operation of the system just described, an electron beam, of constant intensity and of a cross-section small as compared with the area of the targets, is developed by the electron gun, and directed toward the targets 12 and 13. It is assumed that due to the potentials on the deflecting plates the beam has just been removed from contact with the extended portion 13E of the target 13 by motion of the beam toward the deflecting plate 10. This point is indicated at X on the dotted line in Fig. 2, which represents the path of the beam in a plane perpendicular to the axis of the envelope. The potentials are applied, as explained above, to the deflecting plates 8 and 9, and at this time serve to deflect the beam toward the plate 8 until it reaches the point Y indicated on the line A of Fig. 2. During the time the electron beam travels from the point X to the point Y the beam is directed upon the target 12. Thereupon the beam is deflected by plates 10 and 11 toward the plate 11 and directed so as to be upon the target 13 and is further deflected by plates 8 and 9 back to the point X.

The electrons emitted during the period when the beam is deflected from the point X to the point Y reach the target 12 at various points thereon and, due to the shape and position of the target 12, they arrive at these points at substantially the same instant and are all collected simultaneously. Likewise the electrons emitted during the period when the beam is deflected from the point Y back to the point X reach the target 13 at various different points thereon but, due to the shape and position of this target, they arrive at these points at substantially the same instant and are all collected substantially simultaneously. The electrons collected at the ends of the periods X—Y and Y—X produce current pulses of extremely short duration and of high intensity in the transmission line 14.

For the purpose of effecting the required deflection of the beam, voltages of proper phase must be applied, as mentioned above, to the deflecting plates 8 to 11. While it is possible to produce this deflection with square-topped impulses of proper duration and phase, the simplest way of accomplishing the shift of the electron beam from one target to the other is that employed in the arrangement of Fig. 1, wherein sinusoidal voltage waves are applied to the deflecting plates, with the wave applied to the plates 10 and 11 90° out of phase with respect to the wave applied to the plates 8 and 9. While this use of sinusoidal deflecting voltage waves causes the beam to describe an oval path, this is of no disadvantage, since the targets 12 and 13 are made sufficiently wide to allow for the maximum beam deflection toward the deflecting plates 10 and 11.

The required deflecting voltages applied to the deflecting plates 8 to 11 are derived from the output signal by means of the transmission line 20 which is coupled, as explained above, to the transmission line 14. Traveling waves are thereby developed along the transmission line 20 and two voltages, which are 90° out of phase with respect to each other, are readily derived by means of the pairs of contacts 25, 25 and 26, 26 which are effectively spaced one-quarter wave length from each other. These two voltages are applied to the deflecting plates 8, 9 and 10, 11. The desired polarity of deflection is readily obtained by selecting the proper terminals. By proper adjustment of the spacing of the deflecting plates, or by attenuating, by any suitable means, the voltage applied to one set of the deflecting plates, the above described oval path of the electron beam is readily obtained.

The current pulses produced by the intermittent collection of electrons on the targets 12 and 13 develop oscillations in the transmission line 14, at a frequency dependent upon the adjustment of the transmission line. A transmission line 30 can be coupled to the transmission line 14 at suitable points thereon as shown for supplying the energy developed in the line 14 to a load schematically indicated by the block 31.

In Fig. 3 there is shown a tube similar to that of Fig. 1 having a circuit connected thereto providing a modulator system. Like members are indicated by the same numerals as in Fig. 1. Here a modulating signal is applied to the control element 4, by way of a coupling condenser 32 and a resistor 33, for controlling the intensity of the electron beam in accordance with the applied signal. A radio frequency carrier signal supplied from a suitable source is in this case applied to a pair of terminals 35, 35, which are connected to the deflecting plates 8 and 9, so as to cause deflection of the modulated electron beam along the targets in accordance with the frequency of the carrier signal. Here it is again necessary to provide the deflecting plates 10 and 11 with a voltage which is 90° out of phase with respect to the signal output voltage in the transmission line 14. For this purpose a transmission line 20 is coupled to the transmission line 14 and is terminated with a resistor 24 having a value equal to the characteristic impedance of the line. A single pair of sliding contacts 25, 25 supported by means of an insulating member 36 are connected to the deflecting plates 10 and 11 by means of suitable leads 28. By sliding the contacts 25, 25 along the transmission line 20, in which traveling waves are produced, to the proper positions, a voltage which has a phase shift of 90° with respect to the voltage in transmission line 14 is readily derived for the deflecting plates 10 and 11.

Since the number of electrons collected by the targets 12 and 13 varies in accordance with the modulating signal, a modulated carrier signal is developed in the transmission line 14, the effective length of which is made equal to one-quarter of the wave length of the applied radio

frequency carrier signal. A transmission line 30 is preferably coupled to suitable points of the transmission line 14 and supplies the energy developed therein to a load, schematically indicated by the block 31. This load may, for example, consist of a broadcasting antenna, in which case the signal applied by way of condenser 32 would of course be the modulation signal to be transmitted and the signal applied at the terminals 35 would be the carrier wave to be broadcast.

While in the embodiments illustrated means are shown for deriving the required deflecting voltages from the output signal, it will be appreciated that this is of course not essential, inasmuch as separate sources of deflecting voltages can be used which are held in synchronism and in proper phase relation with the output signal.

While there has been described what are at present considered to be the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein, without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim is:

1. The method of electron control which comprises generating a beam of electrons, directing said beam into space, varying the direction of said beam during predetermined time intervals, substantially simultaneously intercepting the electrons of said beam during said time interval, utilizing the intercepted electrons to produce a signal, and utilizing a portion of said signal to control said variation of said beam.

2. The method of signal amplification which comprises generating a beam of electrons, directing said beam into space, deflecting said beam in accordance with a signal, and substantially simultaneously collecting the electrons emitted during portions of the cycle of said signal at points in space reached by said electrons at the termination of the period of each of said portions to produce an amplified signal.

3. The method of signal amplification which comprises generating a beam of electrons, directing said beam into space, deflecting said beam in accordance with a signal, substantially simultaneously collecting the electrons emitted during portions of the cycle of said signal at points in space reached by said electrons at the termination of the period of each of said portions to produce an amplified signal, and utilizing a portion of said amplified signal to control said deflection of said beam.

4. The method of modulation which comprises generating a beam of electrons, controlling the intensity of said beam in accordance with a modulating signal, directing said beam into space, deflecting said beam in accordance with a carrier signal, and substantially simultaneously collecting the controlled electrons directed into said space during portions of the cycle of said carrier signal at points in space reached by said electrons at the termination of the period of each of said portions to produce a modulated carrier signal.

5. The method of modulation which comprises generating a beam of electrons, controlling the intensity of said beam in accordance with a modulating signal, directing said beam into space, deflecting said beam in accordance with a carrier signal, substantially simultaneously collecting the controlled electrons directed into said space during portions of the cycle of said carrier signal at points in space reached by said electrons at the termination of the period of each of said portions to produce a modulated carrier signal, and utilizing a portion of said last-named signal to control said deflection of said beam.

6. An electron control device comprising means for generating free electrons, means for directing said electrons into space, means for cyclically and substantially simultaneously collecting electrons emitted during predetermined periods at points in space reached by said electrons at the end of each of said periods, and means for utilizing the collected electrons to produce a signal.

7. An electron control device comprising means for generating a beam of electrons, means for directing said beam into space, means for moving said beam for a predetermined time interval, and intercepting means spaced sufficiently from the source of said beam of electrons to effect electron accumulation in said space during said interval for intercepting said beam at different distances from said source to collect the electrons constituting said beam during said interval.

8. An electron control device comprising means for generating a beam of electrons, means for directing said beam into space, means for moving said beam for a predetermined time interval, intercepting means spaced sufficiently from the source of said beam of electrons to effect electron accumulation in said space during said interval for substantially simultaneously intercepting the electrons constituting said beam during said interval, and means for utilizing the intercepted electrons to produce a signal.

9. An oscillation generator comprising means for generating a beam of electrons, means for directing said beam into space, means for moving said beam for a predetermined time interval, means for substantially simultaneously intercepting the electrons carried by said beam during said interval, means for utilizing the intercepted electrons to produce a signal, and means for utilizing a portion of said signal to control said movement of said beam.

10. A signal amplifier comprising means for generating a beam of electrons, means for directing said beam into space, means for deflecting said beam in accordance with a signal, and means for substantially simultaneously collecting the electrons emitted during portions of the cycle of said signal at points in space reached by said electrons at the end of each of said portions to produce an amplified signal.

11. A signal amplifier comprising a means for generating a beam of electrons, means for directing said beam into space, means for successively deflecting said beam in opposite directions in accordance with portions of a cycle of a signal, means for substantially simultaneously collecting the electrons emitted during said portions of the cycles at points in space reached by said electrons at the end of each of said portions to produce an amplified signal, and means for utilizing a portion of said amplified signal to control said deflection of said beam.

12. A modulator comprising means for generating a beam of electrons, means for controlling the intensity of said beam in accordance with a modulating signal, means for directing said beam into space, means for deflecting said beam in accordance with a carrier signal, and means for substantially simultaneously collect-

ing the controlled electrons directed into said space during portions of the cycle of said carrier signal at points in space reached by said electrons at the end of each of said portions to produce a modulated carrier signal.

13. A modulator comprising means for generating a beam of electrons, means for controlling the intensity of said beam in accordance with a modulating signal, means for directing said beam into space, means for deflecting said beam in accordance with a carrier signal, means for substantially simultaneously collecting the controlled electrons directed into said space during portions of the cycle of said carrier signal at points in space reached by said electrons at the end of each of said portions to produce a modulated carrier signal, and means for utilizing a portion of said last-named signal to control said deflection of said beam.

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