May 16, 1944. R. M. SMITH 2,349,011

FREQUENCY CONTROL FOR ULTRA HIGH FREQUENCY DEVICES

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Fig. 1.

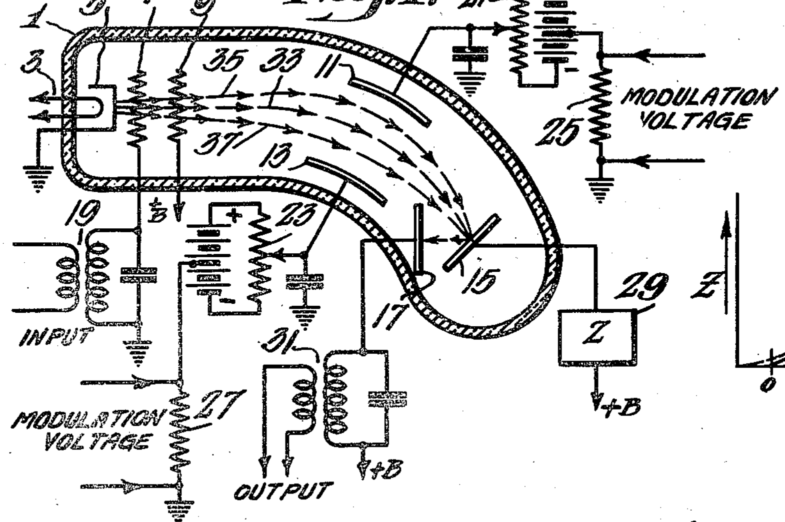


Fig. 4.

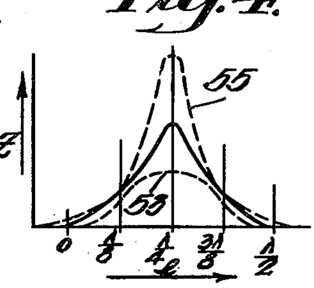


Fig. 2.

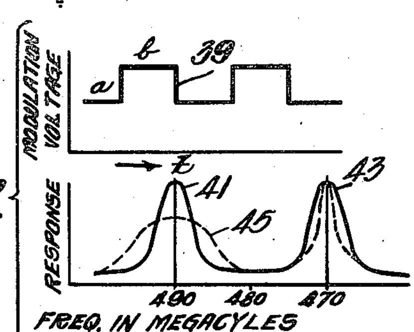


Fig. 3.

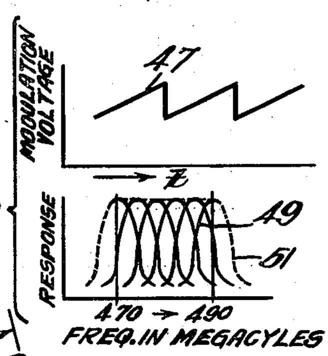
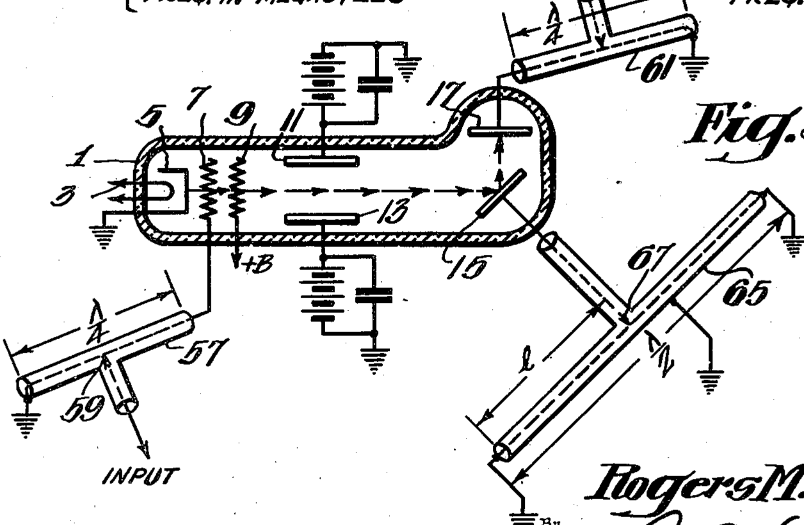


Fig. 5.



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Rogers M. Smith

By [signature]

Attorney

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FREQUENCY CONTROL FOR ULTRA HIGH FREQUENCY DEVICES

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Fig. 6.

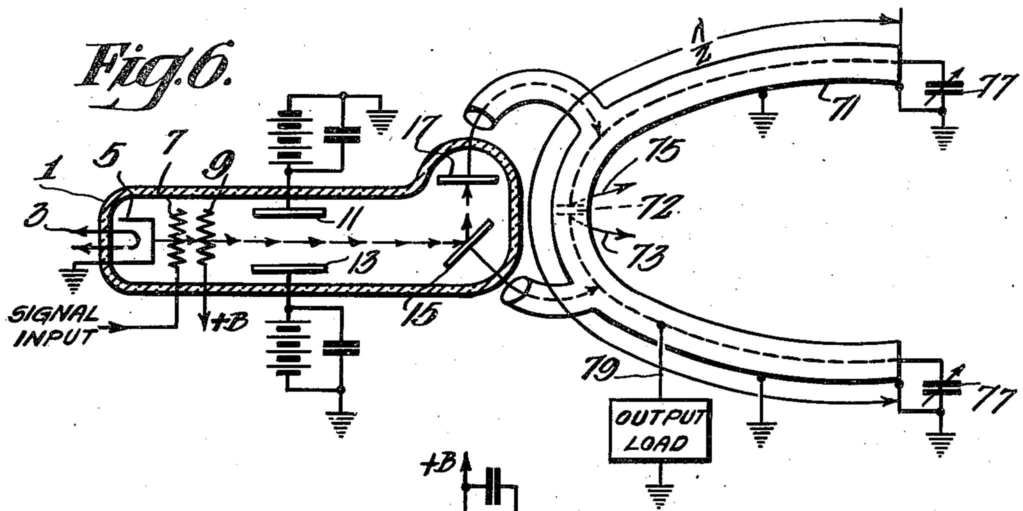
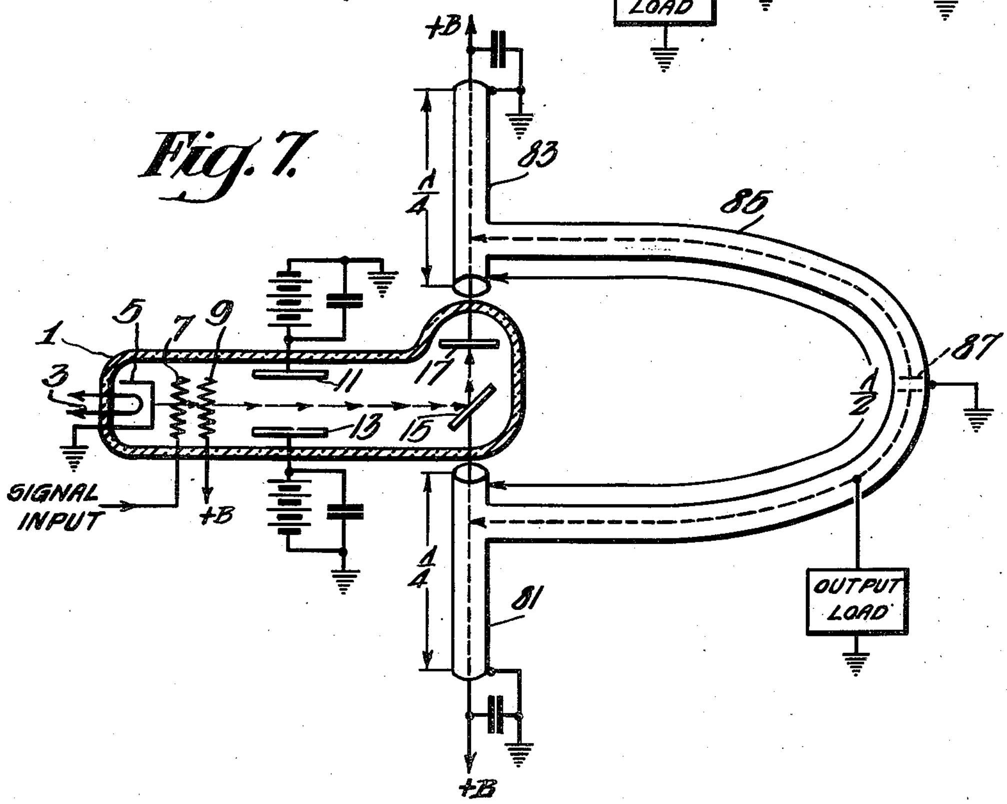


Fig. 7.



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2,349,011

FREQUENCY CONTROL FOR ULTRA HIGH FREQUENCY DEVICES

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Application July 31, 1941, Serial No. 404,856

9 Claims. (Cl. 250—27)

This invention relates to improvements in the frequency controls for ultra high frequency devices and particularly to an ultra high frequency secondarily emissive thermionic tube in which the frequency characteristic is controlled by adjusting the length of the electron paths and hence the electron transit time.

In conventional thermionic tubes operating at frequencies of the order of 100 megacycles per second and downwardly throughout the lower frequencies the transit time of the electrons passing from cathode to anode has a negligible effect on the operating frequency. As the tubes are operated at frequencies of the order of 500 megacycles per second the effects of electron transit time become appreciable, and in fact act as a frequency limiting factor.

While transit time acts as a limiting factor in conventional tubes operated at the lower frequencies, the electron flight time in a tube operated at the higher frequencies may be used to control the frequency, to control regeneration or degeneration, to compensate for circuit variations, and to provide multiple band operation. Thus it is one of the objects of the instant invention to provide means for utilizing the electron transit time to control the operation of an ultra high frequency device. An additional object is to provide means for controlling the electron transit time in a secondary emissive device thereby to control its operation. Another object is to provide improved means in an oscillatory circuit including a secondary emissive device for controlling frequency, regeneration, circuit variations and frequency response characteristic of the circuit.

The invention will be described by referring to the accompanying drawings in which Fig. 1 is a schematic diagram of one embodiment of the invention; Figs. 2, 3 and 4 are graphs illustrating modes of operation; Fig. 5 is a schematic diagram of a modification; and Figs. 6 and 7 are schematic diagrams of push pull circuits embodying the invention. Similar reference characters indicate similar elements in the drawings.

Referring to Fig. 1, within an evacuated envelope 1 are arranged: a heater 3, a cathode 5, a control grid 7, a screen grid 9, a pair of deflecting electrodes 11, 13, a secondary emissive electrode 15, and an anode 17. The control grid 7 is connected through an oscillatory circuit 19 to ground. The oscillatory circuit 19 is coupled or connected to a signal input source. The screen grid is connected to a B voltage source which is not shown.

The deflecting electrodes 11, 13 are connected, respectively, to the adjustable terminals of potentiometers 21, 23. The potentiometers are connected, respectively, through resistors 25, 27, or other suitable inputs for modulation voltages, to ground. The modulation voltages will be hereinafter described. The secondary emissive electrode is connected either directly or through an impedance 29 to a positive terminal of the B voltage source. The anode 17 is connected through an oscillatory circuit 31 to a positive terminal of the B voltage source. The oscillatory circuit may be coupled directly or indirectly to an output or load circuit.

In the normal operation of the device electrons released from the cathode 5 travel along curvilinear paths 33 to the secondary emissive electrode 15 on which the electrons impinge. The impinging electrons release secondary electrons, which travel to the anode 17 and hence through the oscillatory circuit 31 where resonance establishes oscillatory currents. It should be understood that the amplitude of the electronic currents varies as a function of the frequency of the applied signal potentials.

It has been discovered that when the oscillatory circuits have been tuned to a period corresponding to 500 megacycles, by way of example, and the electron transit requires a period of the same order, variations in the electron transit time have a reactive influence on the circuit. The reactive influence may be readily controlled by changing the potentials applied to either or both deflecting electrodes 11, 13. Thus by making electrode 11 more positive, the electrons take the longer path 35, or if electrode 13 is more positive, the electrons follow the shorter path 37. If the electron velocity is constant, the path length determines the electron transit time and thus the magnitude and sense of the reactive effect. By way of example, a 4 percent voltage change in the outer deflecting electrode 9 produced a frequency change of at least 0.25 megacycle at 500 megacycles and in some frequency ranges 0.5 megacycle change accompanied a deflecting potential change of 2 percent. In these ranges calculations showed that the electron transit time approached the period of the operating frequency.

The described method of operation may be used to change the response frequency of the circuit by adjusting the potentiometers 21, 23 without changing the oscillatory circuits. Furthermore, as shown in Fig. 2, a modulation voltage of a square wave form 39 may be applied to the resistors 25 and/or 27 so that alternate frequency responses are obtained.

The one peak 41 corresponds to modulation voltage a and the other peak 43 corresponds to modulation voltage b. If desired, the circuits 19 and 31 may be adjusted so that degeneration occurs at the higher frequency and regeneration at the lower frequency, as the modulation voltages a and b are applied, as shown by the dash line 45.

By applying a sawtooth modulation wave 47 as shown in Fig. 3, the response curve may be made to move through a range of frequencies as represented by a series of response curves 49. If the sawtooth frequency is very high, the resultant response will have a band pass characteristic represented by the dash line 51.

Regeneration may be controlled by varying the impedance 29 to broaden or sharpen the frequency response of the device as shown by the curves 53, 55, respectively, of Fig. 4.

One suitable circuit for controlling regeneration is shown in Fig. 5. The tuned input circuit is represented as a quarter wave concentric line 57 to which the input signal is applied at a suitable impedance point 59. The tuned output circuit is also represented as a quarter wave concentric line 61 to which an output lead 63 may be connected to the line 61 at an appropriate impedance point.

The impedance or regeneration control circuit consists of a half wave concentric line 65 to which the emissive electrode 15 is connected at a chosen point 67 on the inner conductor. The effect of moving the connection as a function of the distance l from the grounded terminal of the line 65 is shown in Fig. 4. In this connection the transit time is first regulated, as previously described, to obtain regeneration in the circuits and then the amount of regeneration may be regulated by the point 67 at which the secondary emissive electrode is connected. The length l is the factor determining the amount of impedance Z which is included in the emission electrode circuit. It has been found that the frequency of the circuit may also be controlled most effectively by varying the impedance Z. This effect has not been shown in Fig. 4.

The insertion of impedance in the secondary emissive circuit makes it practical to employ a push pull output circuit as shown in Fig. 6. In this connection a half wave concentric line 71 is provided. The central portion of the inner conductor includes a blocking capacitor 72 which permits different potentials to be applied to the emissive electrode 15 and the anode 17 by way of leads 73 and 75, respectively. The ends of the line may include variable capacitors 77 for tuning the line. The output load may be applied by tapping the line at a suitable impedance point 79. The push pull type of circuit has twice the power output or the voltage is increased by the ratio $\sqrt{2/1}$ where 1 is the voltage for a single output circuit.

A modification of the push pull circuit is shown in Fig. 7. In the modification the secondary emissive electrode 15 and the anode 17 are connected to the +B source through quarter wave lines 81, 83, respectively. The terminals of a half wave line 85 are connected to points on the quarter wave lines 81, 83 at which the impedances of the several lines are appropriately matched or transformed, if transformation is desired. A blocking capacitor 87 is included in the inner conductor of the half wave line so that different potentials may be applied to the electrodes 15, 17 through the quarter wave lines 81, 83 without the half wave line short circuiting the B voltage source, which is not shown. The output may be derived by tapping the half wave line. In the circuits of Figs. 6 and 7 the potentials of the deflecting electrodes may be adjusted or varied as described in connection with Fig. 1.

Thus the invention has been described as an ultra high frequency device employing a secondarily emissive electrode. The input voltages control the electron stream and hence the secondary electron emission. The operating frequency or period is chosen near the electron transit time which is controlled by means including deflecting electrodes. The electron transit time has a positive or negative reactive effect on the device. The reactive effects may be employed to control the frequency, regeneration or response characteristic. While in the prior art devices the secondary emissive electrode was generally grounded for radio frequency potentials, an impedance is included in the emissive electrode circuit of the instant invention. This impedance may be used to control tuning or may be included in a push pull output circuit. When the device is employed as an oscillator it is preferable to include mutual coupling of the proper sign between the input and output circuits. Such mutual coupling is often present in the ordinary wiring of the circuits, especially when the bypassing is insufficient.

I claim as my invention:

1. An ultra high frequency device including a thermionic tube having an input circuit, an output circuit, and an electron path; means for adjusting the period of said circuits to correspond approximately to the transit time required for electrons to travel said path; and means for varying the electron transit time so that said electrons have a reactive influence on said device.

2. An ultra high frequency device including a thermionic tube having an electron source and a secondary emissive electrode, an input circuit connected to said source, an output circuit and an electron path of controllable length; means for adjusting the frequency of at least one of said circuits to correspond approximately to the transit time for electrons to travel said path; and means for adjusting said path length so that electrons travelling said adjusted path have a reactive effect on said device.

3. In an ultra high frequency device, the combination of a thermionic tube including an input circuit, a source of electrons connected to said input circuit, a secondary emissive electrode, means for deflecting electrons from said source onto said emissive electrode, an anode for collecting electrons emitted from said electrode, a resonant circuit connected to said anode, and means including said deflecting means for varying the length of the path travelled by electrons from said source to said emissive electrode so that the reactive influence of said electrons will vary the frequency characteristic of said resonant circuit.

4. In an ultra high frequency device, the combination of a thermionic tube having a source of electrons, a secondary emissive electrode, and an anode electrode for receiving electrons from said emissive electrode; a variable impedance connected to said secondary emissive electrode; a resonant circuit connected to said anode; means for deflecting electrons from said source onto said electrode; and means including said deflecting means for varying the transit time of elec-

trons travelling from said source to said emissive electrode whereby they have a reactive influence on said resonant circuit.

5. In an ultra high frequency device, the combination of a thermionic tube having a source of electrons, a secondary emissive electrode, and an anode electrode for receiving electrons from said emissive electrode; an impedance connected to said secondary emissive electrode, a resonant circuit connected to said anode; means for deflecting electrons from said source onto said electrode; and means including said deflecting means for varying the transit time of electrons travelling from said source to said emissive electrode whereby they have a reactive influence on said resonant circuit and whereby said impedance controls the response characteristic of said resonant circuit.

6. In an ultra high frequency device the combination of a thermionic tube including a cathode, control electrode, deflecting electrode, secondary emissive electrode, and an anode; an input circuit including said cathode and control electrode; a resonant output circuit effectively connected in push-pull relation between said emissive electrode and said anode; and means including said deflecting electrode for adjusting the transit time of electrons passing from said cathode to said emissive electrode.

7. In an ultra high frequency device the combination of a thermionic tube including a cathode, control electrode, deflecting electrode, secondary emissive electrode, and an anode; an input circuit including said cathode and control electrode; a pair of quarter wave lines connected respectively to said emissive electrode and to said anode; a half wave line having its terminals respectively connected to said quarter wave lines; and means including said deflecting electrodes for influencing reactively the currents in said lines.

8. The method of controlling the frequency response characteristic of an ultra high frequency device including a thermionic tube having an electron source, an input circuit connected to said source, and an output circuit which includes the steps of emitting electrons, directing said electrons to said output circuit, adjusting the periods of said circuits so that they are of the order of the time required for said electrons to travel from said source to said output circuit, and altering said electron travel time so that said electrons have a reactive influence on the frequency response characteristic of said device.

9. The method of varying the frequency characteristic of an ultra high frequency device including an input circuit, an oscillatory output circuit, a cathode, a secondary emissive electrode, a deflecting electrode and an anode, which includes the steps of emitting electrons from said cathode, deflecting said electrons on said emissive electrode, collecting on said anode secondary electrons emitted by said emissive electrode, applying to said oscillatory circuit the currents corresponding to said collected electrons, adjusting the periods of both of said circuits to correspond approximately with the time required for the cathode emitted electrons to said emissive electrode and hence to said anode, and thereafter applying potentials to said deflecting electrodes to establish reactive influences on said oscillatory circuit.

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