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RESONANT CAVITY DEVICE

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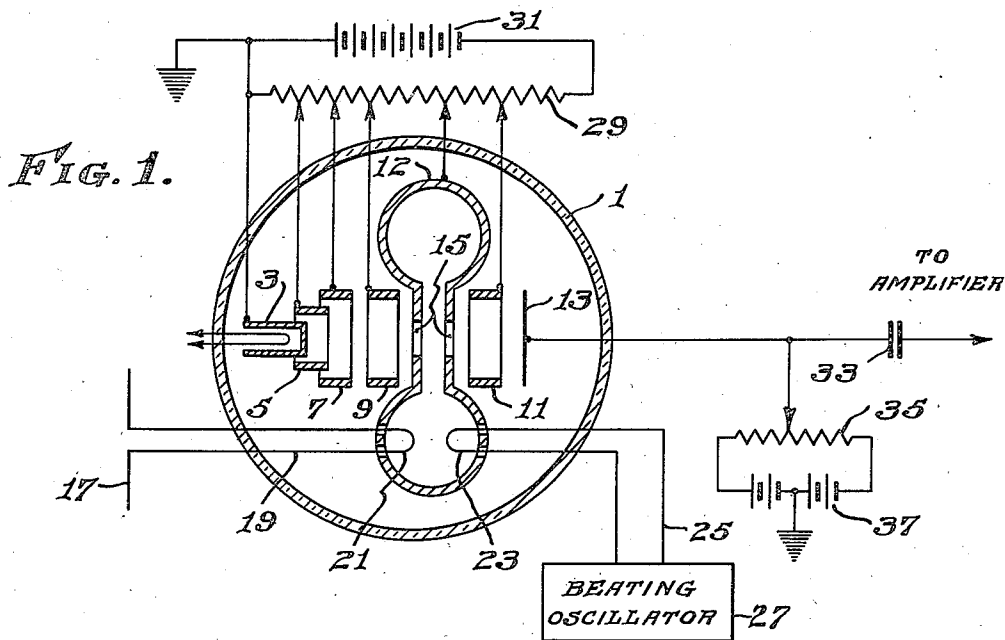
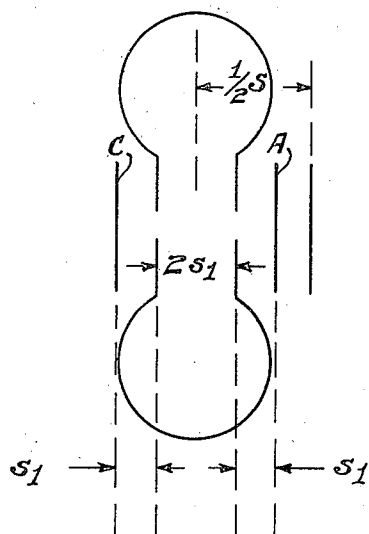


FIG. 2.



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RESONANT CAVITY DEVICE

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9 Claims. (Cl. 250—20)

This invention relates to ultra high frequency devices, and more particularly to an ultra high frequency resonant cavity device for generating, detecting or converting oscillations into currents of low frequency.

The term "ultra high frequency oscillations" is generally applied to electromagnetic oscillations having a frequency of the order of 500 megacycles per second and upward. At the higher frequencies, for example, 3000 megacycles, it has been difficult to generate powerful oscillations and equally difficult to detect efficiently. This difficulty has been mainly due to the space characteristics of the thermionic tubes which are employed.

Among the prior art devices are the magnetron and Barkhausen-Kurz tubes. In these tubes, the radio frequency potentials are applied to the electrodes by means of resonant circuits.

The difficulties of generating or detecting radio frequency oscillations, of a wave length of the order of 10 centimeters, will be appreciated by considering the physical size of a magnetron oscillator in which the anode is a cylinder of the order of 2 millimeters radius and 1 centimeter length. In this arrangement, the anode is subjected to intense heat when even low power oscillations are generated. Thus it is quite apparent that the space limitations of the prior art oscillators have prevented the generation of more than about 10 watts of ultra high frequency oscillatory energy. Furthermore, devices of the aforementioned type are inefficient detectors.

An object of the present invention is to provide means for avoiding the structural limitations by employing tube elements which are not connected by resonant circuits and which do not themselves oscillate, but which direct electrons through a resonant cavity. In other words, the radio frequency potentials will not be applied to the tube elements and thus some of the restrictions on size will be eliminated. As an object of this invention, means will be provided for utilizing a resonant cavity to generate, detect or convert oscillations of a predetermined frequency. It is another object of the invention to provide a resonant cavity having a size corresponding to a predetermined band of wave lengths. It is a further object of the invention to provide means for collecting or inducing electromotive forces within a resonant cavity. A still further object is to provide means for detecting and regenerating ultra high frequency oscillations.

The invention will be described by referring to the accompanying drawing in which Figure 1 is a schematic diagram of one embodiment of the invention; and Figure 2 is a schematic diagram employed in describing the operation of the device.

Referring to Fig. 1, the elements of the thermionic device are suitably supported within an evacuated envelope 1. These elements are: a cathode 3, cylindrical focusing elements 5, 7, phasing electrodes 9, 11, a collecting electrode 13 and a hollow resonant cavity 12 including apertures 15 which are preferably coaxially mounted between the phasing electrodes 9 and 11. A dipole antenna 17 may be connected to a transmission line 19 which includes a loop 21 arranged within the cavity 12 for inducing or collecting ultra high frequency energy. The resonant cavity 12 is preferably but not necessarily of toroidal form so dimensioned that an electromagnetic field of the proper frequency will resonate the cavity and will establish therein oscillations. The frequency, at which resonant oscillations occur, is determined primarily by the dimensions of the cavity. The cavity is preferably bounded by a suitable conductor which includes one or more apertures through which electrons are directed. By way of an analogue, a Helmholtz resonator for sound waves corresponds to the instant resonant cavity for electromagnetic waves. If the device is to be used to convert the ultra high frequency energy by means of a beating oscillator, the currents of the beating frequency may be induced within the cavity 12 by loop 23 terminating a transmission line 25 connected to a beating oscillator 27. The cathode, focusing and phasing electrodes, and resonant cavity are suitably biased by connections to a potentiometer 29 which is connected across a power source 31. The collecting electrode 13 is connected to an amplifier or signal indicating device by a blocking capacitor 33. The collecting electrode 13 may be biased slightly positive or slightly negative by means of the potentiometer 35 and battery 37.

In the operation of the device, an electron beam is established by the cathode 3 and focusing electrodes 5, 7. It should be understood that the first phasing electrode 9 may also focus the beam. This beam is projected through the resonant cavity 12 in which the ultra high frequency field imparts velocity variation to the beam. Some of the higher velocity electrons pass through the cavity and reach the collecting electrode 13. The remainder of the electrons

are reversed and returned to the cavity, again passing through it. The phase of the returning electron groups is adjusted by proper electrode spacing and potential so as to establish oscillations within the cavity, or to increase the amplitude of the oscillations, if oscillations have been established within the cavity.

If the device is being used as a detector, the waves to be detected are impressed upon the dipole antenna 17 and hence induced within the cavity, where they form resonant waves which are reinforced or increased by the regenerative action of the velocity modulated electron beam. If the device is used as an oscillator for the production of power at ultra high frequencies, the power is derived by the currents induced in the loop 21.

By way of example, the following table of resonator voltages was found to give the detection maxima:

V	ΔV	Mean V
1,925	375	1,737
1,550	300	1,400
1,250	220	1,140
1,030	155	950
875	135	807
740	115	682
625	75	587
550		

This series is explainable on the basis of transit time from the resonator center to the plate and return. This time T is given by:

$$T = 3.37 \cdot 10^{-8} S V^{-1/2}$$

Hence

$$\Delta T = -1.69 \cdot 10^{-8} S V^{-3/2} \Delta V$$

or

$$\Delta V = -\frac{V^{3/2} \Delta T}{1.69 \cdot 10^{-8} S}$$

This 3/2 power law is followed by the above data.

Putting $V=1000$, $\Delta V=170$, $S=2.4$, we get $\Delta T=2.17 \cdot 10^{-10}$, experimental value is $3.10 \cdot 10^{-10}$. Also

$$\frac{T}{\Delta T} = \frac{3.37 \cdot 10^{-8} \cdot 2.4}{3.1 \cdot 10^{-10} \cdot 35.4} = 74$$

These results indicate that transit times of an integral number of periods give maximum sensitivity.

Where the electrode spacing of an oscillator is arranged according to Fig. 2 and when s_1 equals the distance from the aperture to the cathode C, s_1 the distance from the aperture to the anode A, V_1 is the potential of the resonator with respect to its cathode, t_1 is electron transit time, V is the electron velocity, m is the electron mass, $\bar{v}$ is the average electron velocity, and e is the electron charge, it can be shown that the equation for electron motion is:

$$\frac{d^2 s}{dt^2} = \frac{e V_1}{m s_1}$$

$$\therefore v = \frac{V_1 e}{m s_1 t}$$

and

$$s = \frac{V_1 e}{2 m s_1} t^2$$

when

$$t = t_1, s = s_1$$

$$\therefore s_1 = \frac{V_1 e}{2 m} t_1^2$$

and

$$\bar{v} = \frac{s_1}{t_1} = \sqrt{\frac{V_1 e}{2 m}}$$

The final velocity for $t = t_1$ is given by

$$1/2 m v^2 = V_1 e \text{ or } v = \sqrt{\frac{2 V_1 e}{m}}$$

$$\therefore \frac{v}{\bar{v}} = 2$$

Hence, if the spacing through the cavity is made twice that from the cavity to the cathode and/or anode, then, when the transit time through the cavity is one-half period, the transit time from cavity to A or to C and back to the cavity will be one period.

Thus, the invention has been described as an ultra high frequency resonant cavity device in which oscillations may be generated or detected. Furthermore, the detection may be of a regenerative character which increases the efficiency of detection about 10 times.

It should be understood that the invention is not limited to the precise arrangement or spacing of the elements shown.

I claim as my invention:

1. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity positioned between said source and said electrode, means for directing electrons from said source through said cavity and toward said collecting electrode, means for adjusting the phase of the electrons passing through said cavity so that velocity variations are established, and a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to the cavity the said passing electrons and for adjusting the phase of electrons returning through said cavity so that the returning electrons establish ultra high frequency waves within the cavity.

2. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity located between said source and said electrode, means for establishing ultra high frequency waves within said cavity, means for directing electrons from said source through said cavity and toward said collecting electrode, means for adjusting the phase of the electrons passing through said cavity so that velocity variations are established, and a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to the cavity the said passing electrons and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the amplitude of the ultra high frequency waves established within the cavity.

3. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity located in operable relation between said source and said electrode, means for directing electrons from said source through said cavity and toward said collecting electrode, means for adjusting the phase of the electrons passing through said cavity so that velocity variations are established, a hollow electrode disposed be-

tween said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to the cavity the said passing electrons and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the amplitude of the ultra high frequency waves established within the cavity by the electrons passing therethrough, and means including said collecting electrode for deriving currents corresponding to said waves.

4. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity operably located between said source and said electrode, means for establishing ultra high frequency waves within said cavity, means for directing electrons from said source through said cavity and toward said collecting electrode, means for adjusting the phase of the electrons passing through said cavity so that velocity variations are established, a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to the cavity the said passing electrons and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the amplitude of the ultra high frequency waves established within the cavity, and means including said collecting electrode for deriving currents corresponding to said waves.

5. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity in operable relation between said source and said electrode, means for establishing within said cavity ultra high frequency waves to be detected, means for applying beating oscillations to said cavity, means for directing electrons from said source through said cavity and toward said collecting electrode, means for adjusting the phase of the electrons passing through said cavity so that velocity variations are established, a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to said cavity said passing electrons and for adjusting the phase of electrons returning through said cavity, and means including said collecting electrode for deriving currents having a frequency corresponding to the beat frequency of the ultra high frequency waves and beating oscillations.

6. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity operably located between said source and said electrode, means for directing electrons from said source through said cavity and toward said collecting electrode, and a hollow electrode disposed between said cavity and

collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to said cavity said electrons directed through the cavity and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the ultra high frequency waves established within the cavity by electrons passing therethrough.

7. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity operably located between said source and said electrode, means for establishing ultra high frequency waves within said cavity, means for directing electrons from said source through said cavity and toward said collecting electrode, and a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to said cavity said electrons directed through the cavity and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the ultra high frequency waves established within the cavity.

8. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity positioned between said source and said electrode, means for directing electrons from said source through said cavity and toward said collecting electrode, a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to said cavity the electrons directed therethrough and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the amplitude of the ultra high frequency waves established within the cavity by electrons passing therethrough, and means including said collecting electrode for deriving currents corresponding to said waves.

9. An ultra high frequency device including a source of electrons, a collecting electrode, a resonant cavity positioned between said source and said electrode, means for establishing ultra high frequency waves within said cavity, means for directing electrons from said source through said cavity and toward said collecting electrode, a hollow electrode disposed between said cavity and collecting electrode electrically biased independently of said cavity and said collecting electrode for returning to said cavity the electrons directed therethrough and for adjusting the phase of electrons returning through said cavity so that the returning electrons increase the ultra high frequency waves established within the cavity, and means including said collecting electrode for deriving currents corresponding to said waves.

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