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ANODE TANK CIRCUIT OSCILLATOR

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Fig. 1.
Line 17-19 May Be
Tuneable In Length

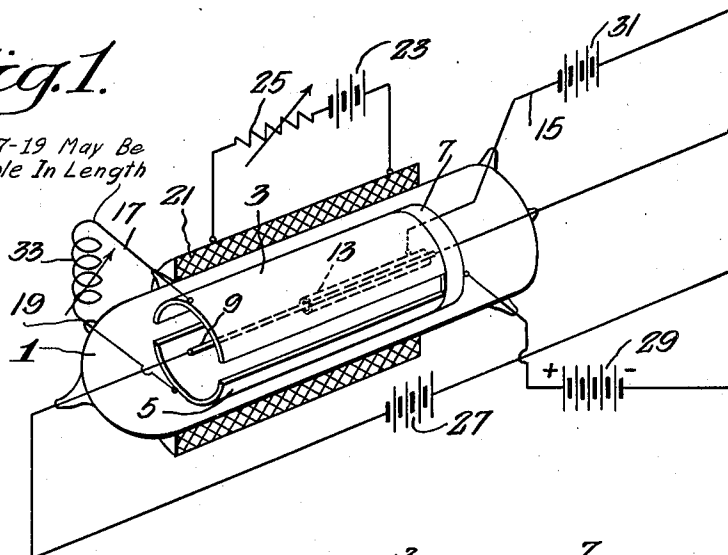
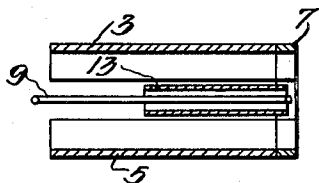


Fig. 2.

Line 17-19 May Be
Tuneable In Length

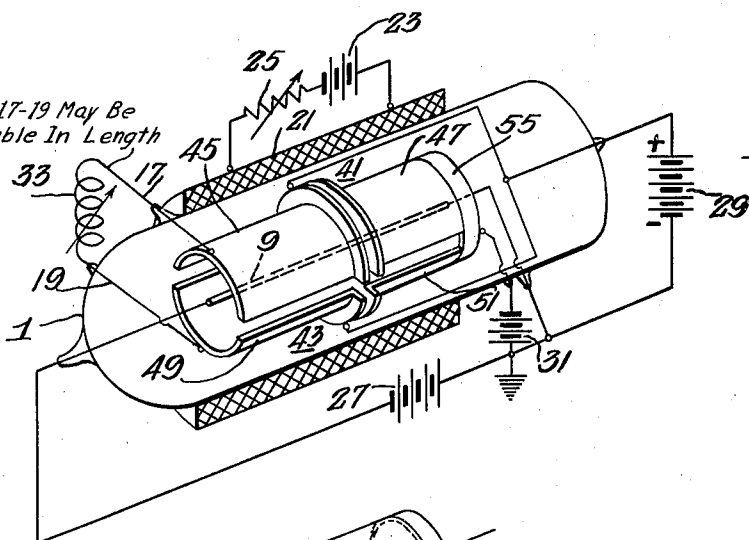
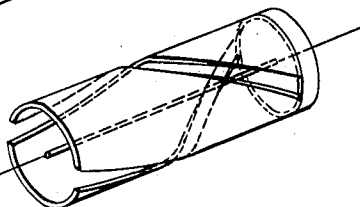


Fig. 3.

Fig. 4.



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ANODE TANK CIRCUIT OSCILLATOR

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8 Claims. (Cl. 250—36)

My invention relates to high frequency oscillators, and more particularly to an improved anode tank circuit oscillator.

U. S. Patent No. 1,978,021 issued to H. E. Hollmann shows the general use of a resonant electrode in ultra-high frequency oscillators. The above patent describes the use of the operating electrodes of a tube as open oscillators, for example as dipole systems directly excited by the electrons which are discharged from a concentrically arranged cathode.

The present invention is concerned with the use of closed oscillatory circuits as anodes, with means for varying the effective frequency of such a system, for increasing its efficiency and for coupling it properly to a load or utilization device.

Briefly, an anode tank circuit oscillator is one in which the anode electrode is so designed that it functions simultaneously both as anode, as a resonant circuit which determines the frequency of oscillation, and as a loaded transmission line by which the power generated may be conveniently utilized.

If the size of resonant anode tubes is not to be excessive, it is apparent that their use is important only at the ultra-high frequencies usually generated by magnetron and Barkhausen-Kurz oscillators, in which the wave length is of the order of a few centimeters. While I have shown my invention in connection with magnetrons, it is, of course, evident that the same idea can be carried out in other tubes.

Various arrangements have been proposed for including self-resonant circuits within a vacuum tube. One of the reasons for this construction is to provide a higher resonant frequency by eliminating connecting leads between the oscillator anode and the resonant circuit. In addition an important advantage is obtained by the elimination of the high capacities between electrodes which are necessarily present when a "lumped" inductance system is used.

In earlier types of high frequency oscillators the anode plates have been used both as anode and as the shunt capacity for the resonant tank circuit. It was found that this system was limited by reason of the fact that if the plates or anodes were kept small enough to oscillate at a high frequency they were unduly overheated. If their size was increased to permit sufficient heat dissipation then the shunt capacity was increased and the obtainable frequency greatly reduced.

It was also found to be difficult to control the frequency of resonant electrode oscillators of the prior art due to the fact that any attempt to include a portion of the resonant circuit in a circuit external to the tube resulted in an immediate decrease in the resonant frequency. Thus, where the frequency must be as high as

possible, it is necessary to include the entire resonant circuit within the tube. In the prior art the oscillation frequency of the tube has therefore been predetermined by the dimensions of the tube structure.

It obviously becomes desirable to provide means for attaining the maximum frequency with a construction suitably designed to provide proper heat dissipation, and still permit control of the resonant frequency of the oscillatory circuit.

It is, of course, true that the magnetic field strength and the applied voltages influence the frequency of oscillation of a magnetron. However, with an internal resonant circuit, maximum efficiency and output are only obtained at the resonant frequency of the circuit. Consequently, such a method of frequency control is not satisfactory.

It is, therefore, an object of this invention to provide means for adjusting the operating frequency of an anode tank circuit oscillator without lowering the output or decreasing the efficiency.

It is a further object of this invention to provide means for coupling a load to a standing wave tank circuit oscillator.

It is a further object of this invention to provide means for increasing the efficiency of a standing wave tank circuit oscillator.

It is a still further object of this invention to provide an ultra-high frequency oscillator which is capable of generating oscillations at a higher power and frequency than before obtainable.

A still further object of my invention is to provide an ultra-high frequency oscillator which does not radiate power from its oscillating electrodes, but in which the power generated may be efficiently transferred to operate a remote utilization device.

This invention will be better understood from the following description when considered in connection with the accompanying drawing. Its scope is indicated by the appended claims. Similar reference numerals refer to similar elements throughout the several drawings.

Referring to the drawing,

Figure 1 is a perspective view of a magnetron illustrating one embodiment of my invention,

Figure 2 is a sectional view of the electrode construction of the magnetron illustrated by Fig. 1,

Figure 3 is another embodiment of my invention, and

Figure 4 shows an alternative anode construction in which the anode sections spiral about the cathode.

Referring to Fig. 1, a glass envelope 1 contains a pair of semi-cylindrical anodes, 3 and 5, which are supported at one end by a mounting ring 7. A linear cathode 9 extends axially throughout the length of the anodes 3 and 5, and through the

mounting ring. Connecting leads from the cathode are brought out through the envelope in any convenient manner. A substantial portion of the cathode is surrounded by a concentric metallic sleeve 13, which is supported by any suitable means in the center of the mounting ring. The sleeve is insulated from both the cathode and the mounting ring. This construction is more clearly shown in Fig. 2. A connecting lead 15 from the sleeve is brought out through the glass envelope. A connection is brought out also from the free end of each of the anodes 3 and 5, as shown at 17 and 19.

The oscillator is supplied with an axial magnetic field, as, for example, by a coil 21 which is energized by a battery 23 through a variable resistor 25. The connections which complete the circuit include a cathode energizing battery 27, an anode potential source, such as a battery 29, which is connected between one end of the cathode and the mounting ring 7, and a sleeve potential battery 31 which is connected between the sleeve 13 and cathode so as to place the sleeve at a negative potential with respect to the cathode.

The anode electrodes 3 and 5 form a closed anode tank resonant circuit. When energized the open ends of the electrodes will be of opposite instantaneous polarity, and a voltage node will exist at the mounting ring 7. The ring may therefore be at ground potential with respect to radio frequency currents, and is therefore a convenient point at which the direct current potential lead may be attached.

The anode tank circuit is energized by electrons from the cathode so that standing waves are set up in the manner which is well known to those skilled in the art. By connecting a load across the open ends of anodes, the oscillatory power may be derived from the tube elements and utilized in any desired manner. In Fig. 1 a load is shown connected across the anode leads 17 and 19. It is to be understood that the leads may be kept so short that their reactance is negligible or the length may be so adjusted that the effective reactance of the load gives the desired frequency. For example, if the leads are effectively a half wave length long, the load which is connected across their outer terminals is reproduced within the tube and appears effectively across the ends of the anodes. On the other hand, the length may be effectively a quarter wave length, in which case an impedance inversion takes place, and a high impedance at the outer end is reproduced as a low impedance across the anodes.

The oscillatory tank comprising anodes 3 and 5 is itself a closed circuit and very little energy is radiated directly therefrom. This is highly desirable, as it permits the point of radiation to be controlled, and permits radiation at a convenient point some distance from the tube itself. It is evident that this greatly simplifies the construction of beam radiators which use reflectors, for the tube itself need not be located in the reflector.

Another important feature of my invention is that the resonant frequency of the anode tank circuit may be varied by changing the load reactance. While the anode arrangement of this invention is not strictly identical to a conventional transmission line, due to the fact that it is energized over its length rather than by the application of a driving voltage at a particular point, it has been discovered that the following

relation is true for both conventional lines and the anode tank circuit illustrated:

$$X = Z_0 \tan \frac{2\pi l}{\lambda}$$

where X = the reactance of the load

Z_0 = the characteristic impedance of the line or tank circuit

l = the length of the line or tank circuit

λ = the wavelength of the oscillations.

It is therefore evident that for a given arrangement having a fixed length and a certain characteristic impedance, the wavelength is a function of the load reactance.

Theoretically the absolute value of the load impedance may vary between zero and infinity. When the load impedance is infinitely high, it has no effect on the resonant circuit, and its natural wavelength will be unaffected. However, as the load impedance approaches zero, the tank circuit is effectively short-circuited at both ends, and it becomes effectively a half-wave resonant circuit, and consequently the frequency of oscillation is doubled.

It is possible, according to this invention, to vary the frequency of a standing wave tank circuit oscillator over a two-to-one range. By choosing proper values of load resistance and reactance, an oscillator is obtained which combines all the advantages of a resonant anode oscillator with the flexibility of an external tank circuit oscillator, and is capable of delivering more power at higher frequencies.

The purpose of the sleeve 13 surrounding the cathode will now be explained. Since the entire anode is at a high direct current potential with respect to the cathode, electrons are rapidly attracted to it. Those electrons which are released in the vicinity of the voltage node of the anodes do not contribute as much energy to the oscillations as to those at the high radio frequency potential end. It is therefore desirable to reduce the number of the comparatively inactive electrons to improve the efficiency of the system. This is the purpose of the sleeve. The negative bias on it keeps the electrons in the more active region of the circuit. It is desirable to have this sleeve insulated from the cathode so that it may be maintained at a negative potential with respect to it.

Fig. 3 illustrates another embodiment of my invention which performs the function which has just been described in a different manner.

It has been pointed out above that it is desirable to avoid a lumped capacitance-lumped inductance circuit in order to eliminate the undesired effects of the high shunt capacities that result. This is best accomplished by maintaining a symmetrical resonant line, such as that shown, in which the capacitance and inductance are uniformly distributed over the entire circuit. It is not desirable to greatly alter the electrical characteristics of such a resonant circuit, and therefore it is best not to replace the relatively inactive portion of the tank in attempting to reduce the losses which have been described. The construction shown in Fig. 3 completely effectuates the desired purpose.

Each anode section 41, 43 has been divided into two parts 45, 47 and 49, 51, respectively, which are insulated from each other with respect to direct currents, but which are effectively bypassed to each other for the ultra-high frequency oscillatory currents. The bypass may conveniently take the form of radial flanges, as shown in Fig. 3,

or, as an alternative, by overlapping the adjacent edges.

The sleeve 13 is not now required. With these exceptions, the device shown in Fig. 3 is identical to that shown in Fig. 1, and therefore need not be described again in detail. The connections differ only by the substitution of the inner section of the anodes for the sleeve, that is, battery 31 is now utilized to place a negative potential on the relatively inactive anode section 47, 51, to thereby confine the electronic action to the outer sections of the anodes 45 and 49. Thus the efficiency has been increased without affecting the uniform characteristic of the tank circuit.

Fig. 4 illustrates a type of anode construction which permits the overall anode length to be reduced without reducing the effective length. It is difficult to produce a strong magnetic field throughout the length of a long anode. This is especially true when magnetic pole pieces are placed in line with the anode axis. The spiral anode permits the distance between the pole pieces to be reduced and therefore permits high flux densities to be more easily obtained. Such an anode structure may be utilized with the cathode sleeve shown in Fig. 1 or the divided anode shown in Fig. 3. It may also consist of more than two spiraled sections.

It has also been discovered that this spiral anode can be used to increase or decrease the frequency of oscillation. Since the electrons within the anode follow spiral paths as they progress along the cathode axis, their speed relative to the anode sections which are passed is increased by making the anode plates spiral in an opposite direction, and decreased by making the anode plates spiral in the same direction.

While I have described my invention with reference to several particular types of anodes in a magnetron oscillator, it is to be understood that the invention is also applicable to other anode types, such as those having three or more sections, for example, and to other types of oscillators. By combining the functions of a closed resonant line with the functions of an anode, I have produced an oscillator which is capable of generating oscillations at a higher frequency and at a higher power than before possible. I have further made possible means for deriving the power from the oscillator and controlling its frequency, and I have increased its efficiency by limiting the electrons to the active portion of the circuit.

I claim as my invention:

1. In an electron discharge device the combination which includes a cathode and a concentric cylindrical anode, said anode being divided into two segments comprising a closed oscillatory circuit and substantially a quarter wave length long at the operating frequency, said segments being connected at one end by a shorting conductor of negligible length with respect to said wave length, and a magnetizing coil surrounding and substantially coextensive with said anode for producing a magnetic field throughout the entire region within said anode.

2. In an electron discharge device the combination which includes a cathode and a concentric cylindrical anode, said anode being longitudinally divided into two anode segments connected together at one end to form a closed oscillatory

circuit, means for producing standing waves on said anode segments out of phase with respect to each other, and means including a variable impedance external to said device and connected between the open ends of said anode segments for varying the distribution of said standing waves.

3. In an electron discharge device the combination which includes a cathode and a concentric cylindrical anode, said anode being longitudinally divided into two segments connected together at one end to form a closed oscillatory circuit, and means external to said device and connected between the open ends of said anode segments for varying the resonant frequency of said anode segments.

4. A magnetron oscillator including cathode and anode electrodes and means for producing a longitudinal magnetic field, said anode comprising two semi-cylindrical segments concentrically disposed about said cathode, comprising a closed oscillatory circuit, and substantially a quarter wave length long at the operating frequency, means for producing standing waves at said operating frequency on said segments, and a variable impedance external to said device connected between the open ends of said segments by a pair of conductors a half wave length long at said operating frequency for varying the resonant frequency of said segments.

5. In an electron discharge device the combination which includes a cathode and a concentric cylindrical anode, said anode being longitudinally divided into two segments, said segments being connected at one end by a conductor of negligible length with respect to said wave length and constituting a closed oscillatory circuit, and means connected across the open ends of said segments for varying the effective resonant frequency of said oscillatory circuit.

6. In an electron discharge device the combination which includes a cathode and a concentric cylindrical anode, said anode being longitudinally divided into two segments joined at one end, and constituting a closed oscillatory circuit, means for reducing the flow of electrons between said cathode and the portion of said anode adjacent said end, and means external to said device for varying the resonant frequency of said oscillatory circuit.

7. A device of the character described in claim 1 in which said anode comprises two segments spiraled about said cathode so that the overall length of said anode is reduced while the effective length of said segments is unchanged.

8. In an electron discharge device the combination which includes a cathode and a concentric cylindrical anode, said anode being longitudinally divided into two anode segments, said anode segments being connected at one end by a shorting conductor of negligible length with respect to a wave length at the operating frequency and comprising a closed oscillatory circuit, said segments further being discontinuous with respect to direct current in a direction parallel to said cathode, and means for applying energizing potentials of different intensity with respect to said cathode to parts of said segments which are separated by said discontinuity.