Feb. 11, 1947. L. MALTER 2,415,749

ELECTRON DISCHARGE DEVICE WITH BEAM DEFLECTING RESONATOR

Filed June 30, 1943 2 Sheets-Sheet 1

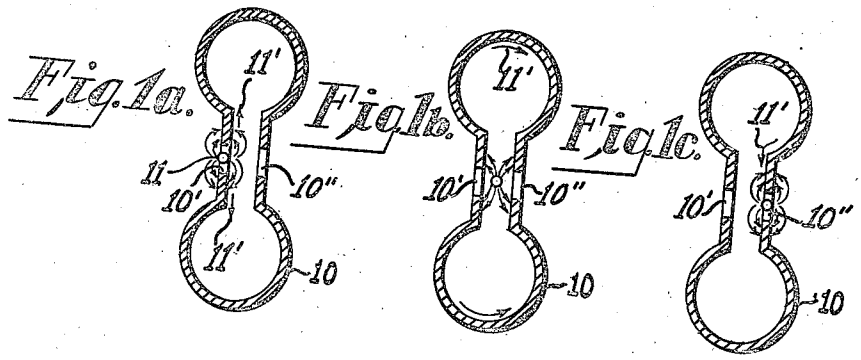

Fig. 1a. Fig. 1b. Fig. 1c.

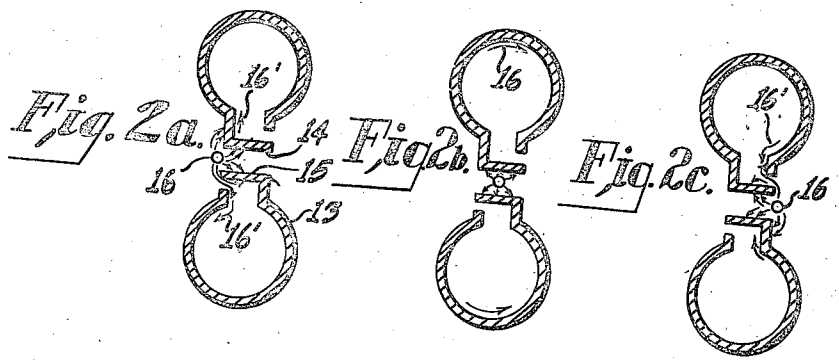

Fig. 2a. Fig. 2b. Fig. 2c.

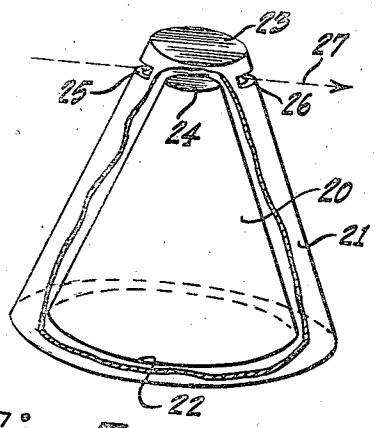

Fig. 3.

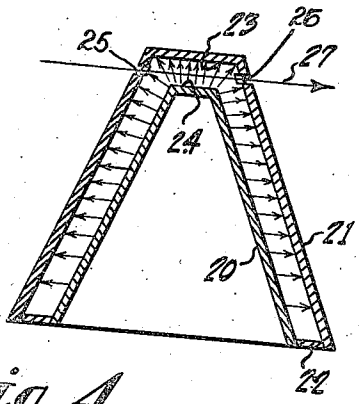

Fig. 4.

INVENTOR
LOUIS MALTER
BY Charles McClair
ATTORNEY

Feb. 11, 1947. L. MALTER 2,415,749

ELECTRON DISCHARGE DEVICE WITH BEAM DEFLECTING RESONATOR

Filed June 30, 1943 2 Sheets-Sheet 2

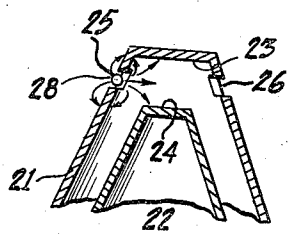

Fig. 5a.

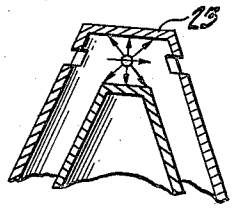

Fig. 5b.

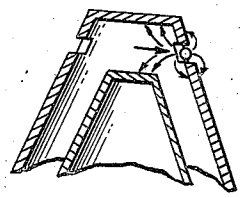

Fig. 5c.

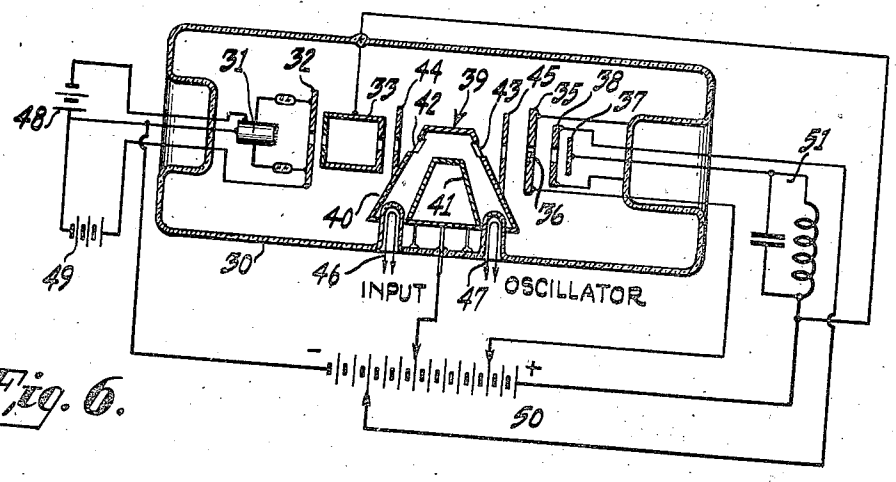

Fig. 6.

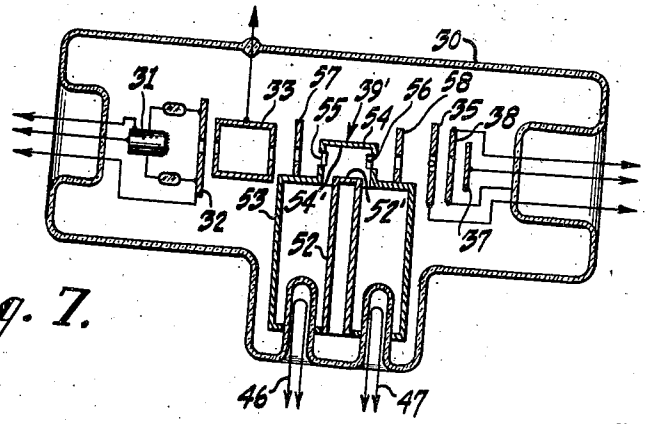

Fig. 7.

INVENTOR
LOUIS MALTER
BY Charles McCain
ATTORNEY

Patented Feb. 11, 1947

2,415,749

UNITED STATES PATENT OFFICE

2,415,749

ELECTRON DISCHARGE DEVICE WITH BEAM DEFLECTING RESONATOR

Louis Malter, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application June 30, 1943, Serial No. 492,804

11 Claims. (Cl. 315—5)

1

My invention relates to electron discharge devices useful at ultra high frequencies and particularly to devices of this kind utilizing beams directed through cavity resonators.

In ultra high frequency receiving tube design, one of the chief concerns is to provide a tube or electron discharge device having a low noise factor, that is a high ratio of signal-to-noise in the output of the tube. Because cavity resonators are particularly suitable for use as ultra high frequency circuits, and because they can be readily combined with electron discharge tube structure, it is becoming common practice to utilize cavity resonators in electron discharge devices used at ultra high frequencies. The use of so-called beam deflection types of tubes have also proved particularly useful at ultra high frequencies and beam deflection tubes of the cavity resonator type have been utilized.

However, the noise factor in tubes of this kind is large, partly because of the fact that shot effect or current density modulations in the electron beam initiated at the electron source induce noise voltages and currents in the cavity resonator as a result of the passage of the beam through the resonator. These induced noise voltages in turn cause velocity modulation of the electron beam as it passes through the resonator, and thus the noise voltages may be amplified by the tube itself. These amplified noise voltages form a significant and sometime major fraction of the total noise produced by the receiving system. In beam deflection type tubes it has been found that the optimum deflection sensitivity results when the transit time of the electron between the deflecting surfaces is equal to substantially a half period of the applied controlling voltages between the surfaces. Unfortunately this is the condition under which the noise voltage produced is a maximum when resonators are utilized.

It is, therefore, an object of my invention to provide an electron discharge device useful at ultra high frequencies and in which the signal-to-noise ratio is high.

Another object of my invention is to provide an electron discharge device useful at ultra high frequencies and utilizing a beam of electrons directed through cavity resonators and having improved operating characteristics.

A more specific object of my invention is to provide a beam deflection tube useful at ultra high frequencies and employing resonators and in which the induced input noise is eliminated or reduced to a negligible value.

2

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawings in which Figures 1, 1*a*, 1*b*, 1*c* and 2, 2*a*, 2*b*, 2*c* are schematic diagrams illustrating the problem for which my invention provides a solution, Figure 3 is a perspective partly in section of a cavity resonator made according to my invention, Figure 4 is a longitudinal section of the cavity resonator shown in Figure 3. Figures 5*a*, 5*b* and 5*c* diagrammatically represent the operation of the device shown in Figures 3 and 4, Figure 6 is an electron discharge device embodying my invention and its associated circuit, and Figure 7 is a modification of the electron discharge device shown in Figure 6 and also embodying my invention.

In electron discharge devices employing a beam of electrons variations in current density will be present due to shot effects or the lack of uniform emission from the surface of the cathode. The electron beam hence has current density variations along the beam and in passing through a resonator will induce a noise voltage within the resonator, which in turn will impress a velocity modulation on the electrons in the beam. This induced noise voltage may under certain conditions amplify the original noise component in the beam so as to decrease the signal to noise ratio in the output of the tube, a very undesirable characteristic. A more detailed explanation of this action is found below.

In Figures 1*a*, 1*b* and 1*c* are shown transverse sections of a cavity resonator 10 and the electrical effects produced within the resonator by charge 11 as it passes through the resonator in its passage between the apertures 10′ and 10″. In Figure 1*a* the charge is just entering the aperture 10′ and its image charge is partially reflected on the outside surface of the resonator and the inside surface of the resonator as indicated by the arrow lines. The arrow lines 11′ indicate the induced current resulting from the reflected image charge on the interior surface of the resonator. Assuming that the transit time of the charge or electron from 10′ to 10″ is one-half period of the induced current and voltage within the resonator, and assuming that the resonator has a natural frequency of operation such that the transit time of the electron between 10′ and 10″ is equal to a half period, it will be observed, as shown in Figure 1*b*, that when the charge 11 is half way between the apertures 10′ and 10″ the induced

charge 11' has arrived at a position mid-way between the opposed surfaces adjacent the apertures 10' and 10''. This reflected image charge which travels around the interior surface of the resonator has at the end of a half period reached aperture 10'' as indicated in Figure 1c. However, charge 11 has also arrived at the same point so that the total charge at aperture 10' is twice that due to the charge 11 arriving at aperture 10'. This represents the worst condition of induced noise since twice the voltage differential due to charge 11 now exists between apertures 10' and 10'', assuming that the charge represents the shot effect or variation from the average current density of the beam passing through the resonator. It is obvious if the transit time of the electrons through the resonator is more or less than a half period that the resulting voltage differential between the surfaces adjacent apertures 10' and 10'' will be less than maximum. This induced noise voltage, however, will velocity modulate the electrons in the beam passing through the resonator, so that the resultant density modulation in the output of the tube appears as an amplified noise of the original noise in the beam.

In Figures 2*a*, 2*b* and 2*c* is shown a cavity resonator 13 provided with deflecting electrode elements 14 and 15 in accordance with the customary practice. As shown by arrows, as charge 16 enters the space between the deflecting electrodes 14 and 15, the lines of force extend from the charge to the walls within the resonator again inducing a current 16' which results in a double charge at the exit aperture as the charge 16 leaves the space between the deflecting electrodes. As pointed out above, when the transit time of the charge or electron through the resonator is substantially equal to a half period, the resulting induced noise voltage and current is a maximum.

I have found that if the beam of electrons through the resonator is made to move at right angles to the electric field within the resonator and if there is no fringing field immediately outside this electric field with which the electrons can have any relation, that the induced noise components become a minimum and under ideal conditions will be zero. A resonator which accomplishes this end is disclosed in Figure 3. It comprises essentially a pair of coaxial coextensive tubular members 20 and 21 comprising a pair of spaced hollow truncated cones joined at one end, for example, by conducting ring 22 and having oppositely disposed parallel surfaces at the other end of the members, as indicated at 23 and 24. Oppositely disposed apertures 25 and 26 are provided in the outer member 21 registering with the space between surfaces 23 and 24 so that a beam of electrons 27 may be directed between the surfaces 23 and 24 of the resonator. The arrow lines illustrate the electric field within the resonator at some arbitrary instant when the resonator is in oscillating condition with the maximum voltage and hence the maximum electrostatic field between the surfaces 23 and 24.

The reason that shot effect or pre-existing current density variation will not introduce a voltage within the resonator shown in Figures 3 and 4 may best be illustrated by Figures 5*a*, 5*b* and 5*c*. As the charge 28 enters the aperture 25 its image is reflected on the inner and outer walls of the resonator but its image is reflected at the same time to substantially the same extent on both surfaces 24 and 23 so that there is little if any resulting potential difference which will cause a

current flow along the inner walls of the resonator from surface 23 to 24. The reflected image on the inner surface of member 21 travels with the charge in its passage through the resonator. Thus at all times there is no resultant flow of radio frequency current within the resonator and hence no induced voltage which will cause velocity modulation of other electrons within the beam which may pass through the resonator.

The above principles are employed in connection with an electron discharge device illustrated schematically in Figure 6. In this embodiment of my invention an envelope 30 has mounted at one end a preferably indirectly heated cathode 31 of the beam forming type provided with apertured beam forming member 32 to provide and direct a beam of electrons which may pass through an accelerator and focusing member 33, which after passing through the resonator designated generally at 39 is deflected across the apertured electrode element 35 provided with a rod 36 resulting in a double aperture, a secondary electron suppressing member 38 to the collector 37 which may be connected to an output circuit 51.

In accordance with my invention I provide a resonator of the type described above, between the accelerating and focusing member 33 and apertured electrode element 35. This resonator is provided with a pair of apertured elements 44 and 45 for shielding the space between the other electrodes and the resonator. The beam is directed through the aligned apertures 42 and 43 and between the inner surfaces of members 40 and 41 in the manner described above, and as a result is periodically deflected across the aperture in electrode 35. The necessary biasing voltages are shown at 48, 49 and 50.

The electron discharge device may be utilized either as a detector or amplifier by applying only an input voltage through coupling loop 46, or as a mixer for superheterodyne operation by introducing in addition an oscillator voltage by means of coupling loop 47. The resultant deflected beam may be deflected across apertured electrode 35 and the current finally collected on electrode 37 to which the output circuit 51 is connected.

In a modification shown in Figure 7 like numerals designate the same parts as in Figure 6. However, the resonator employed comprises a pair of coaxial cylindrical tubular members 52 and 53 closed at the lower ends and provided at their upper end with a cup-shaped member 54, its inner surface being opposite to the upper end of the inner tubular member 52, and providing the parallel surfaces 54' and 52' between which the electron beam is directed through the apertures 55 and 56 and the apertured elements 57 and 58. The device in Figure 7 functions in the same manner as the device shown in Figure 6.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is:

1. An electron discharge device having a cathode means for providing a stream of electrons

and a collector for receiving said electrons, and deflecting means in the path of said stream of electrons for deflecting said stream of electrons across said collector, and including an elongated cavity resonator, said cavity resonator having at one end oppositely disposed surfaces lying in planes parallel to the path of said stream of electrons and between which surfaces an alternating high frequency field is developed during operation of said electron discharge device, the stream path lying between said oppositely disposed surfaces, and being exposed substantially only to the field between said oppositely disposed surfaces.

2. An electron discharge device having a cathode means for providing a stream of electrons and a collector for receiving said electrons, and deflecting means in the path of said stream of electrons for deflecting said stream of electrons across said collector, and including a cavity resonator, said cavity resonator comprising a pair of coaxial concentric substantially coextensive similarly shaped hollow members in spaced relationship and having oppositely disposed surfaces lying in planes parallel to the stream path and between which surfaces an alternating high frequency field is developed during operation of said electron discharge device, the stream path lying between said oppositely disposed surfaces, said stream of electrons being exposed substantially only to the field between said oppositely disposed surfaces.

3. An electron discharge device having a cathode means for providing a beam of electrons and a collector for receiving said electrons, and deflecting means in the path of said beam of electrons for deflecting said beam of electrons across said collector, and including a cavity resonator, said cavity resonator comprising a hollow member having a reentrant portion spaced from an opposite inner wall, said reentrant portion and said opposite inner wall having oppositely disposed plane surfaces lying parallel to and on opposite sides of the beam path, and between which surfaces an alternating high frequency field is developed during operation of said electron discharge device, the beam path lying between said oppositely disposed surfaces, the walls of said cavity resonator being provided with apertures through which said beam path lies the spaces between said plane surfaces being offset with respect to the space confined by the rest of said resonator whereby the beam of electrons is exposed substantially only to the field between said oppositely disposed surfaces.

4. An electron discharge device having a cathode means for providing a stream of electrons and a collector for receiving said electrons, and deflecting means in the path of said stream of electrons for deflecting said steam of electrons across said collector, and including a cavity resonator, said resonator comprising a pair of nested truncated cone-shaped members, the truncated ends lying in spaced parallel planes, and providing parallel surfaces between which an alternating high frequency field is developed during operation of said electron discharge device, the stream path lying between said oppositely disposed surfaces.

5. An electron discharge device having a cathode means for providing a stream of electrons and a collector for receiving said electrons, and deflecting means in the path of said stream of electrons for deflecting said stream of electrons across said collector, and including a cavity resonator, said cavity resonator including a pair of coaxial tubular members forming a coaxial line and closed at one end, the inner tubular member being closed at its other end and a cup-shaped member positioned over said other end of said inner tubular member and closing the other end of the outer tubular member, said cup-shaped member and the closed end of said inner tubular member providing parallel surfaces between and parallel to which the path of the stream of electrons is directed, and between which surfaces an alternating high frequency field is developed during operation of said electron discharge device.

6. An electron discharge device having cathode means for providing a stream of electrons and a collector for receiving said electrons, and a cavity resonator positioned between said cathode means and said collector and including a pair of coaxial concentric substantially coextensive tubular members having adjacent ends at one end of said tubular members joined to close said end, the other end of said inner tubular member being closed by a plane member providing a plane surface and the other end of the outer member being partially closed by an inwardly extending ring-like member and an inverted cup-shaped member on said ring-like member and closing the end of said outer member and having a plane surface spaced from the plane surface of the inner member and parallel thereto, the path of the stream of electrons lying between the plane surfaces of the cup-shaped member and said inner member.

7. An electron discharge device having cathode means for providing a stream of electrons and a collector for receiving said electrons, and a cavity resonator positioned between said cathode means and collector for periodically deflecting said stream of electrons, said resonator including a pair of nested truncated shaped hollow members closed at their ends and enclosing a resonant space, the inner surfaces of the smaller ends of the hollow members providing a pair of opposed plane surfaces parallel to the stream path and between which the stream path lies, the outer member being provided with apertures aligned with said cathode means and said collector through which the stream of electrons is directed.

8. An electron discharge device having cathode means for providing a stream of electrons and a collector for receiving said electrons, and a cavity resonator positioned between said cathode means and collector for periodically deflecting said stream of electrons, said resonator including a pair of nested truncated shaped hollow members closed at their ends and enclosing a resonant space, the inner surfaces of the smaller ends of the hollow members providing a pair of opposed plane surfaces parallel to the stream path and between which the stream path lies, the outer member being provided with apertures aligned with said cathode means and said collector through which the stream of electrons is directed, and an apertured electrode positioned between said collector and said resonator.

9. An electron discharge device having cathode means for providing a stream of electrons and a collector for receiving said electrons, and a cavity resonator positioned between said cathode means and collector for periodically deflecting said stream of electrons, said resonator including a pair of nested truncated shaped hollow members closed at their ends and enclosing a

resonant space, the inner surfaces of the smaller ends of the hollow members providing a pair of opposed plane surfaces parallel to the stream path and between which the stream path lies, the outer member being provided with apertures aligned with said cathode means and said collector through which the stream of electrons is directed, and an apertured electrode positioned between said collector and said resonator, and means on the outside of said resonator and shielding the apertures within said resonator and provided with apertures aligned with the apertures in the resonator.

10. An electron discharge device having a cathode for providing a beam of electrons and a collector for receiving said electrons, and means in the path of said beam of electrons for periodically deflecting said beam and including a cavity resonator, said cavity resonator including a pair of coaxial tubular members forming a coaxial line and closed at one end, the inner tubular member being closed at its other end and a member closing the other end of the outer tubular member, said last mentioned other ends of said inner and outer tubular members being spaced from each other and providing parallel surfaces, the outer tubular member having apertures registering with the space between said parallel surfaces, said surfaces being parallel to the beam path and between which the beam path lies, said surfaces being adapted to have an alternating high frequency field developed therebetween during operation of said electron discharge device.

11. An electron discharge device having a cathode for supplying a beam of electrons and a collector for said beam of electrons, and a cavity resonator positioned between the cathode and the collector and including an elongated hollow conducting member, said hollow conducting member having a reentrant portion extending from one end toward the other but spaced from the opposite inner wall of said hollow conducting member, said opposite inner wall and said reentrant portion having plane surfaces parallel to each other, said hollow conducting member having oppositely disposed apertures aligned with the space between said plane surfaces, the beam path lying through said apertures and between said plane surfaces, said surfaces being adapted to have a high frequency field developed therebetween during operation of said device, said beam path being exposed to said field substantially only between said spaced parallel surfaces.

LOUIS MALTER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,272,165	Varian et al.	Feb. 3, 1942
2,275,480	Varian et al.	March 10, 1942
2,190,511	Cage	Feb. 13, 1940