Aug. 21, 1951 H. J. McCARTHY 2,565,387

INTERDIGITAL MAGNETRON

Filed Oct. 31, 1946 2 Sheets-Sheet 1

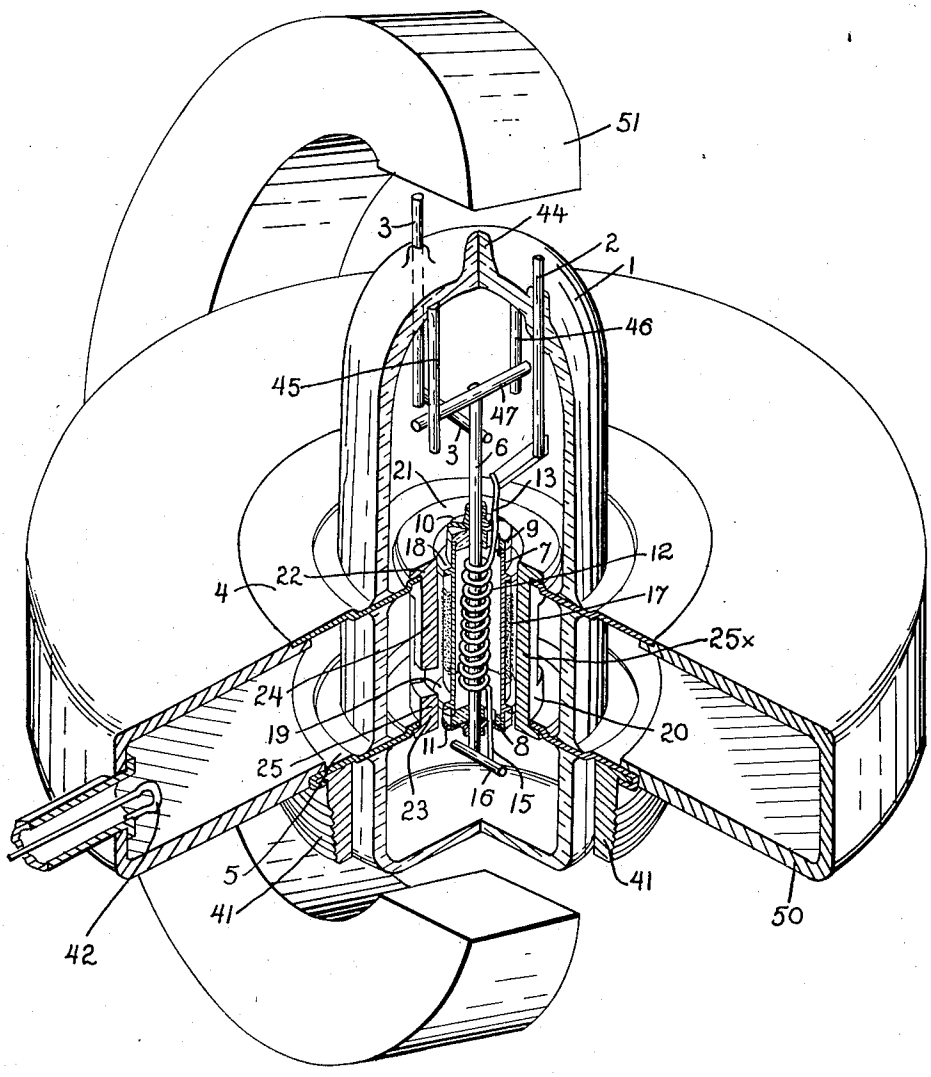


Fig. 1

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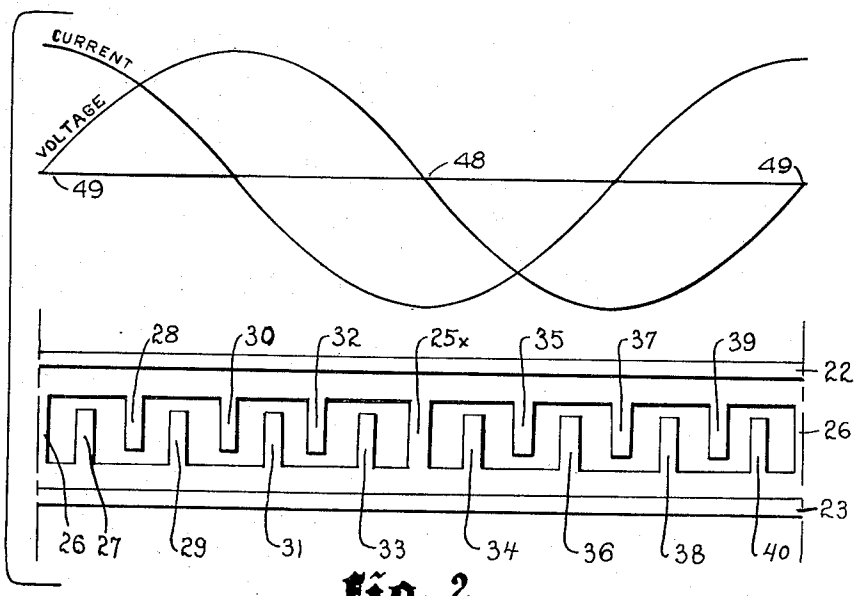


Fig. 2

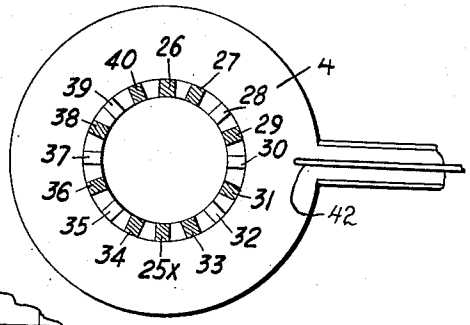


Fig. 3

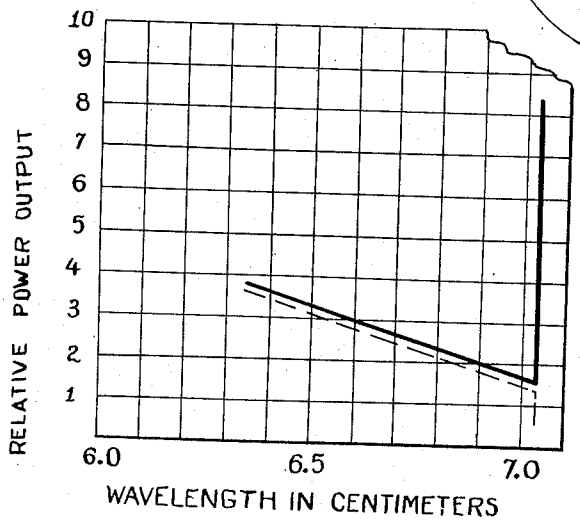


Fig. 4

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UNITED STATES PATENT OFFICE

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INTERDIGITAL MAGNETRON

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13 Claims. (Cl. 315—40)

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This invention relates to microwave devices and particularly to microwave generators such as interdigital magnetrons and the like.

Such devices have previously comprised an anode having two oppositely facing sets of conducting fingers or teeth arranged on the surface of a cylinder or the like, the sets being intermeshed but not in contact, with the circuit between the two sets of teeth completed through a resonant cavity.

In such an arrangement there are radial modes of oscillation and circumferential or angular modes. In the latter, the field strength varies around the cylinder formed by the teeth, and the coupling is best when the coupling loop is placed in the plane of the voltage maximum. However, as the coupling is increased, or the anode voltage raised, the voltage maxima tend to shift away from the loop, and may eventually shift 90°, under which condition the device may oscillate strongly with no power output to the coupling loop. This mode of operation is described in copending applications Serial No. 619,289, filed September 29, 1945, by Donald L. Benedict, and Serial No. 719,414, filed December 31, 1946, by Robert M. Bowie.

I have found that this may be prevented by short-circuiting the two sets of teeth at the voltage nodes, preferably by making the teeth at the nodes longer than the other teeth and long enough to touch the ring which usually connects the other set of teeth. This allows oscillations only for those modes at which a voltage node occurs at the short-circuited teeth. The angular mode of oscillation can no longer shift around the toothed cylinder, and the radial mode is short-circuited.

Diametrically opposite teeth may be short-circuited for the fundamental angular mode, and additional teeth may be short-circuited if harmonics are preferred. Shorted teeth have increased the power output five times in some cases.

The further objects, advantages and features of the invention will be apparent from the following specification, taken in conjunction with the accompanying drawings.

Figure 1 is a partially cut-away view of a device according to the invention;

Figure 2 is a developed view of the opposing anode teeth showing the short-circuiting teeth and the variation of voltage and current along the anode;

Figure 3 is a schematic plan view showing the position of the coupling loop with respect to the teeth; and

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Figure 4 is a curve of power output against wavelength as the distance between the teeth is varied.

In Figure 1, the evacuated glass envelope 1 has sealed therethrough the cathode lead-in wires 2 and 3 and the annular metal discs 4 and 5. Lead-in wire 3 is bent to support the wire 6 along the axis of the envelope 1. The cathode sleeve 7 is concentric with and supported from the wire 3 by the washers 8, 9 which close the ends of the cathode sleeve 7. Connecting straps 10, 11 hold sleeve 7 to the wire 6 and insure firm electrical connection therewith. The cathode heater coil 12 surrounds the wire 6 but is spaced or electrically insulated therefrom to prevent shorting. One end 13 of heater coil 12 is connected to lead-in wire 2, the other end 15 to support wire 16 welded T-like to wire 6, the back bone of the cathode structure as a whole. Sleeve 7 may be of nickel, preferably highly purified, and may be coated with an electron emitting surface 17 preferably of barium, strontium and calcium oxides. Guard washers 18 and 19 may be used at each end of the emitting surface 17, but will be spaced from the anodes 20, 21. These anodes 20, 21 comprise rings 22, 23 transverse to the longitudinal axis of the cathode with the fingers or teeth 24, 25 extending parallel to the cathode sleeve 7.

The fingers, such as 24 extending downward from the top ring 22 mesh or interleave with those extending upward from the bottom ring 23 but do not touch them except for the two diagonally opposite fingers 25x and 26 which are in electrical contact with the opposing rings. The remaining fingers 27 to 40 inclusive, do not contact their opposing rings. This is shown in Figure 2, where the ring is developed.

Rings 22 and 23 are firmly connected electrically and mechanically to, respectively, annular discs 4 and 5, which extend through the glass envelope 1, being sealed thereto in the usual manner well-known in the art. The lower ring 5 has attached to itself a flanged screw-threaded metal cylinder 41 to facilitate placing the tube in a suitable cavity or socket.

The annular discs 4 and 5 are connected together externally by the metal piece 50 to form a resonant cavity. The coupling loop 42 should be in a plane perpendicular to the plane of the shorted teeth 25x and 26, and in a plane passing through the axis of the cylinder formed by the teeth.

A magnet 51, is used to produce a longitudinal field through the tube.

The sealed exhaust tip 44 is merely the tubulation from which the envelope or tube was exhausted. The longitudinal wires 45 and 46 affixed to the transverse wire 47, in turn affixed to the backbone wire 6, aid in supporting the cathode sleeve 7.

In operation, a suitable heater voltage is applied to the lead-in wires 2 and 3, to raise the cathode sleeve 7 and its coating 17 to a temperature sufficient for copious electron emission, and a voltage applied between lead-in wire 3 and the anodes to cause electrons to be directed from sleeve 7 to the anodes 20, 21. The electron motion due to this voltage will be radial. A magnetic field is then applied along the axis of the tube and in the space between the cathode sleeve 7 and the anodes 20, 21. This deflects the electrons in a direction normal to their radial path, causing a precession of electrons before the teeth 25 to 43, inclusive, in the usual magnetron manner, causing oscillations in the anode circuit when the voltage and field move the electrons at the proper speed to excite some mode of the anode structure.

In the first mode, sometimes called the radial mode, the field strength varies radially along the cavity, and is constant angularly. In this mode, the cavity has considerable influence on the frequency. With the contacting teeth in the structure shown, this mode is short circuited.

The contacting teeth do not, however, short-circuit the angular mode, because in this mode the oscillations follow the zig-zag path between teeth (the cavity having a little effect except as a coupling means), and the voltage and current distributions around the ring are as shown in Figure 2, where the ring is shown in developed form. The shorted teeth are at the voltage nodes 48, 49.

Figure 6 is for a tube having two opposite teeth 0.005'' longer than the others, and shows the power output against wavelengths of oscillation, the wavelengths being changed by moving the teeth closer together until they contact. The solid line is for a coupling loop perpendicular to the plane of the teeth, and the dotted lines for a loop in that plane. When the longer teeth meet, the power in the latter loop drops sharply to zero, while the power in the other loop rises from 1.8 to 8.5 watts. In getting the data for this curve one set of teeth was mounted on a flexible diaphragm which could be moved back and forth at its center from outside the tube until the longer teeth were shorted to the other part of the anode.

If the wavelength variation possible with such a diaphragm is desired, and the advantage of the shorted teeth desired at all wavelengths, a flexible short-circuiting tooth is necessary. For example, the shorting tooth, projecting from one ring, may slide within a split-cylinder contacting it and attached to the other ring.

What I claim is:

1. In an interdigital magnetron, an anode comprising two oppositely placed sets of teeth, each set coaxial with the other and each set comprising a series of electrically connected spaced teeth arranged longitudinally along the surface of an imaginary cylinder, the teeth of the two sets being in contact at least at one of the voltage nodes of a predetermined mode of oscillation, the remaining teeth of the two sets being spaced from each other.

2. In an interdigital magnetron, an anode comprising two oppositely placed sets of teeth, each set coaxial with the other and each set comprising a series of electrically connected spaced teeth arranged longitudinally along the surface of an imaginary cylinder, the teeth of the sets being in contact only at two diagrammatically opposite points.

3. A resonator circuit comprising two oppositely placed sets of teeth, each set coaxial with the other and each set comprising a series of electrically connected spaced teeth arranged longitudinally along the surface of an imaginary cylinder, the teeth of the two sets being in contact at least at one of the voltage nodes of a predetermined mode of oscillation, the remaining teeth of the two sets being spaced from each other.

4. A resonator circuit comprising two oppositely placed sets of teeth, each set coaxial with the other and each set comprising circular connecting means and a series of electrically connected spaced teeth arranged longitudinally along the surface of an imaginary cylinder, the majority of the teeth of each set being separated from the other set of electrically connected teeth, said sets embodying isolated diametrically opposite conductive portions interconnecting the two sets of teeth and their circular connecting means.

5. A microwave generator comprising an insulating envelope, a cylindrical cathode within said envelope, a first conducting ring concentric with said cathode and having spaced teeth extending normally to the plane of said first ring, a second conducting ring concentric with said cathode and having spaced teeth extending normally to the plane of said second ring, said second and first rings being coaxial so that their teeth intermesh along an imaginary cylindrical surface, the teeth of the two sets being in contact at least at one of the voltage nodes of a predetermined mode of oscillation, the remaining teeth of the two sets being spaced from each other.

6. A microwave generator comprising an insulating envelope, a cylindrical cathode within said envelope, a first conducting ring concentric with said cathode and having spaced teeth extending normally to the plane of said first ring, a second conducting ring concentric with said cathode and having spaced teeth extending normally to the plane of said second ring, said second and first rings being coaxial so that their teeth intermesh along an imaginary cylindrical surface, the teeth of the sets being in contact only at two diametrically opposite points.

7. The combination of claim 5, including a pair of spaced annular conducting discs, each of said discs being affixed to one of said rings, each of said discs extending through said envelope, a metal path connecting said discs outside said envelope to form a resonator cavity, and a coupling loop in said cavity and perpendicular to the plane of said diametrically opposite teeth.

8. In an interdigital magnetron, an anode comprising two oppositely placed sets of teeth, each set coaxial with the other and each set comprising a series of electrically connected spaced teeth arranged longitudinally along the surface of an imaginary cylinder, certain of the teeth of the two sets interconnecting the sets of teeth at least at one of the voltage nodes of a predetermined mode of oscillation, the remaining teeth of the two sets being spaced from each other, a resonant cavity encircling and interconnecting said sets of teeth, and a coupling loop extending into said cavity in a radial plane perpendicular to the radial plane containing said interconnecting teeth.

9. In an interdigital magnetron, an anode comprising two oppositely placed sets of teeth, each set coaxial with the other and each set comprising a series of electrically connected spaced teeth arranged longitudinally along the surface of an imaginary cylinder, the teeth of one set being in contact with teeth of the other set only at two diametrically opposite points, a resonant cavity encircling and interconnecting said sets of teeth, and a coupling loop projecting into said resonant cavity in a radial plane perpendicular to the plane of said diametrically opposite contacting teeth.

10. An interdigital magnetron comprising an insulating envelope, a cylindrical cathode within said envelope, a first conducting ring concentrically about said cathode near one end thereof, a second conducting ring concentrically about said cathode near the opposite end thereof, teeth extending from said first and second rings respectively along the surface of an imaginary cylinder, the teeth extending from each ring being interposed between the teeth extending from the other ring, and discs fixed to each of said rings and sealed through the wall of said envelope so as to afford external circumferential terminals for said rings, the teeth of each ring being separated from the teeth of the opposite ring except for certain teeth of each ring at voltage nodal points which interconnect said rings.

11. An interdigital magnetron including a cylindrical cathode, an anode assembly including a ring concentrically around each end of said cathode, each ring having teeth extending along the surface of an imaginary cylinder and between the teeth of the opposite ring, the fingers of each ring being separated from the opposite ring except for a minor proportion of teeth extending from one ring to the other to establish voltage nodal points.

12. An interdigital magnetron including a cathode and an anode assembly of opposite anode members including two sets of teeth disposed along the surface of an imaginary cylinder substantially coaxially about said cathode, the fingers of each set having an interconnecting ring and being interposed between the fingers of the opposite anode member, the fingers of each anode member being separated from the opposite anode member except for a minor proportion of teeth extending from one ring to the other for the purpose of fixing a voltage node.

13. A high frequency device including two sets of fingers disposed in an imaginary cylindrical surface, a resonant cavity encircling said fingers, and embodying a pair of axially spaced rings, the fingers of each set extending between the fingers of the other set and each being connected to only one of said rings except for a minor proportion of fingers which extend from one ring to the other to establish nodal points.

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