United States Patent [19]

Ryabinin et al.

[11] **3,882,351**

[45] **May 6, 1975**

[54] **MICROWAVE ELECTRON TUBE**

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[22] Filed: **Apr. 15, 1974**

[21] Appl. No.: **461,236**

Related U.S. Application Data

[63] Continuation of Ser. No. 278,013, Aug. 4, 1972, Pat. No. 3,805,111.

[52] **U.S. Cl.** **315/39;** 315/39.51; 331/97; 331/101

[51] **Int. Cl.** **H01j 7/46;** H01j 19/80

[58] **Field of Search** 315/39, 39.51; 331/97, 331/101

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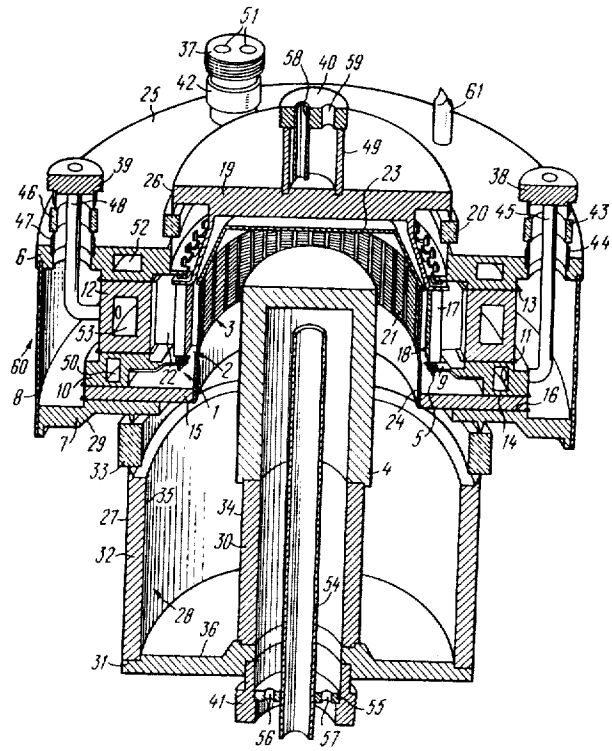
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Assistant Examiner—Saxfield Chatmon, Jr.
Attorney, Agent, or Firm—Holman & Stern

[57] **ABSTRACT**

A microwave electron tube with electrodes - a cathode, an anode and at least one grid. The cathode, the grid and the high-frequency leads coupled to them form the input circuit of the device. The anode, the grid and the high-frequency leads coupled to them form the output circuit of the device. Electric coupling between at least one of the electrodes and its high-frequency lead is accomplished by means of at least one microwave line section. One of the conductors of the microwave line is connected to the electrode and the other conductor, to its high-frequency lead. The two conductors are shorted at the ends opposite to the points at which they are connected to the electrode and to the high-frequency lead and are constructed in the form of surfaces of revolution the size of which is selected so that at the points of connection the impedance is substantially inductive. Such construction of the device makes it highly suitable for use in microwave power amplifiers which operate within a wide frequency band and provides a high efficiency and a high power gain of the device.

10 Claims, 14 Drawing Figures



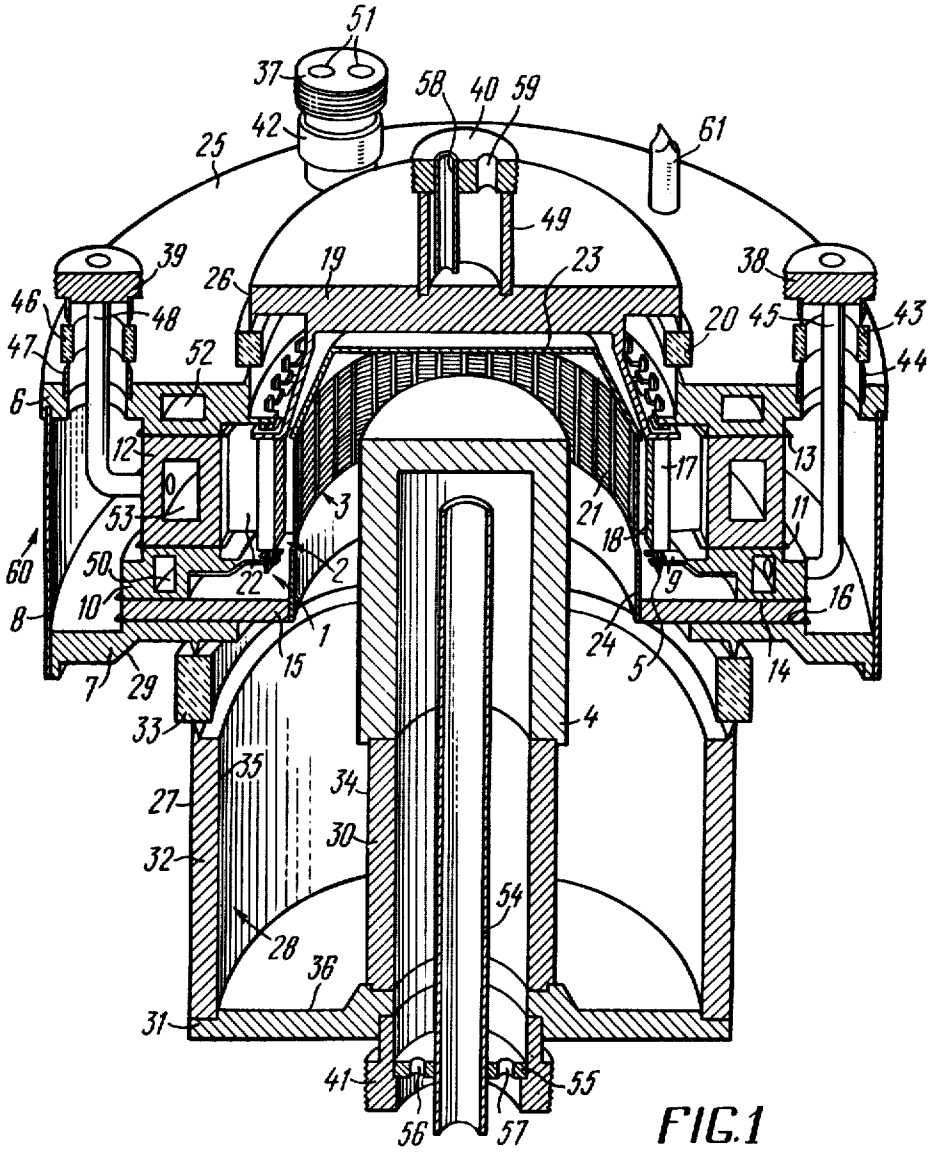

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FIG.1

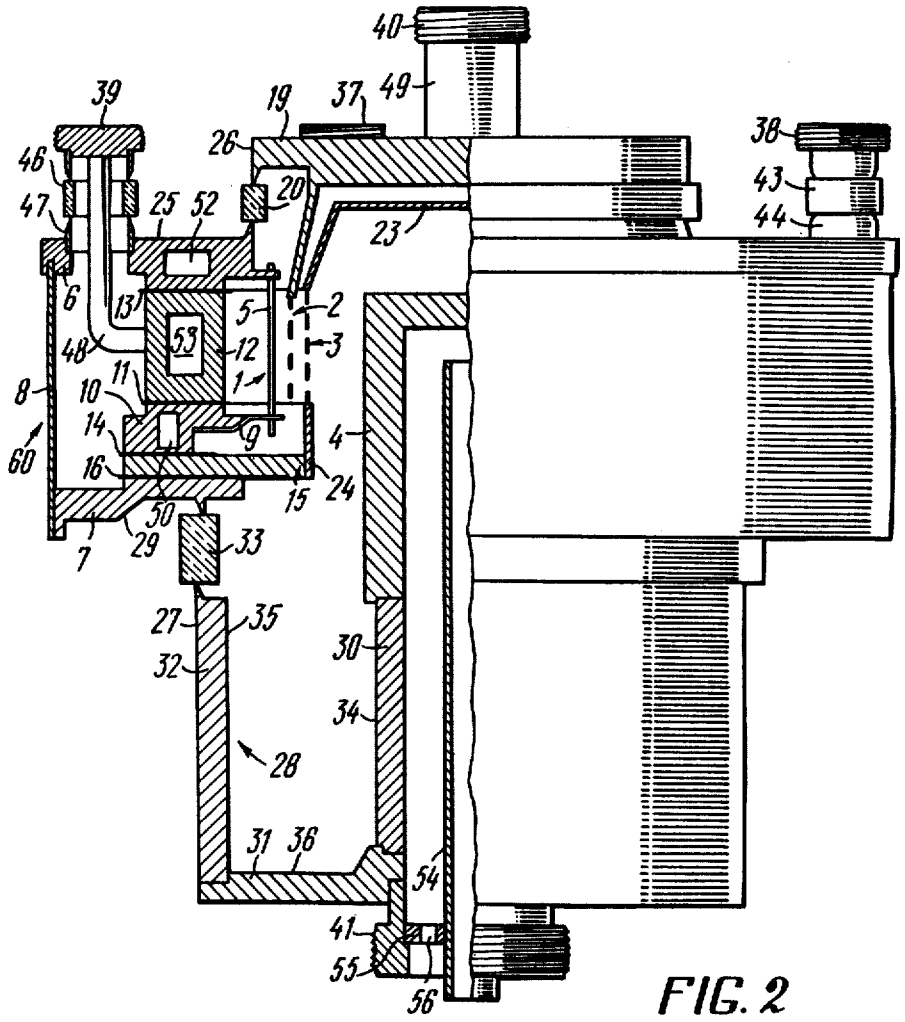

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FIG. 2

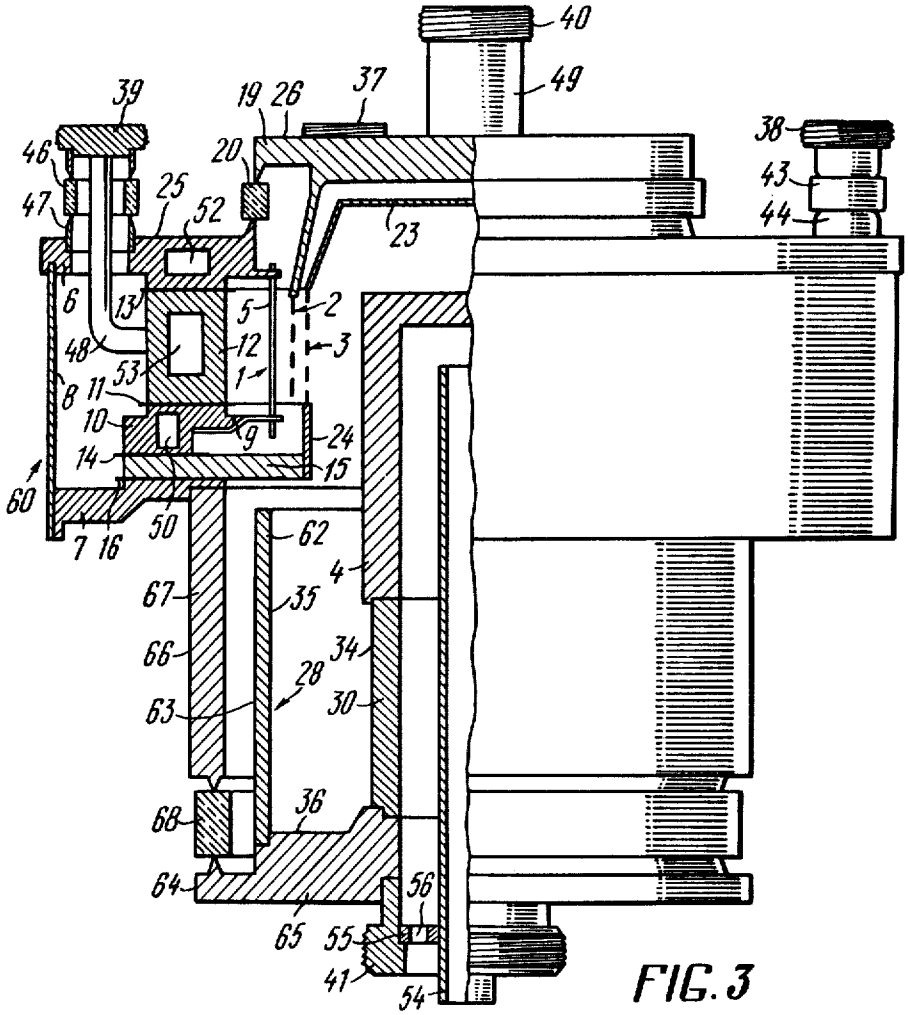

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FIG. 3

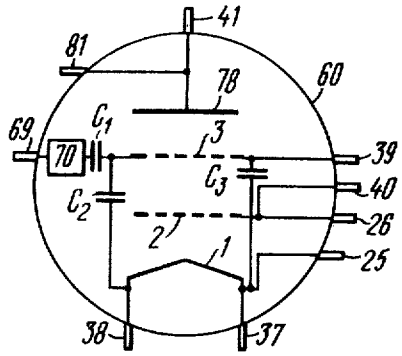


FIG. 6

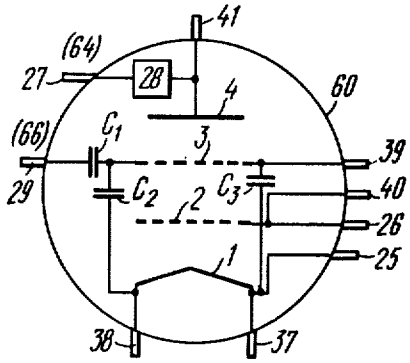
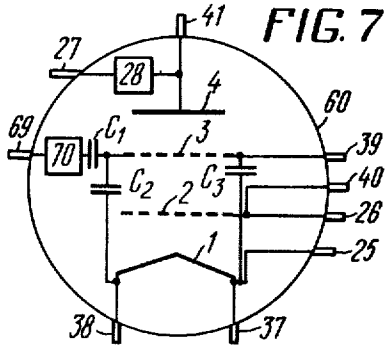


FIG. 4

FIG. 7



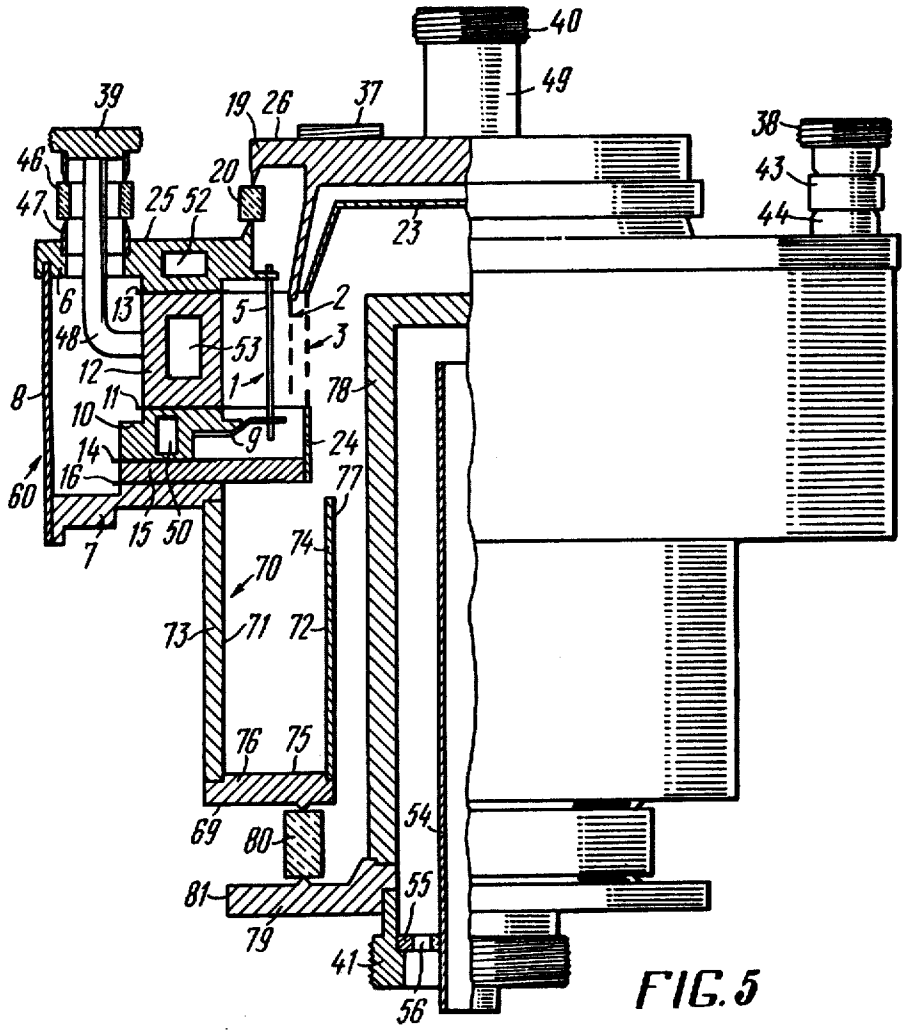

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FIG. 5

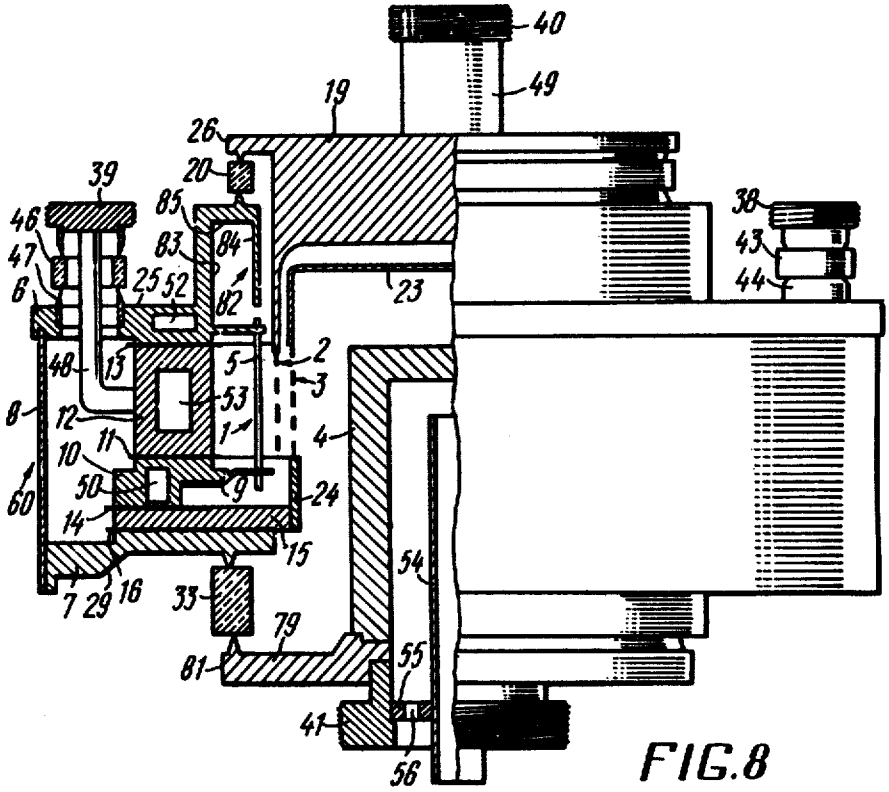

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FIG.8

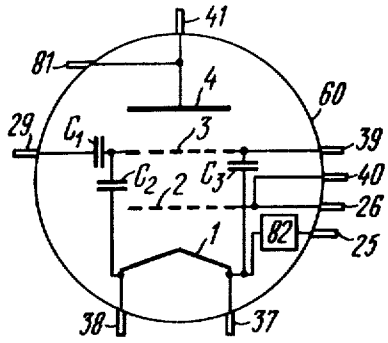


FIG. 9

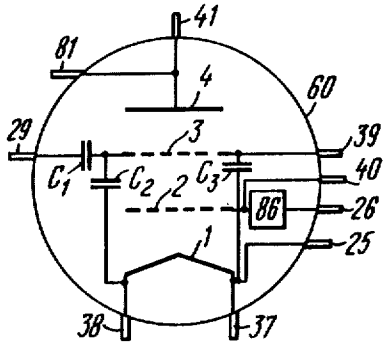
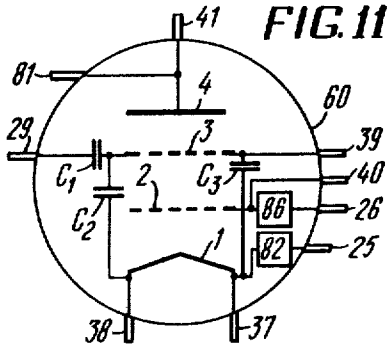


FIG. 10

FIG. 11



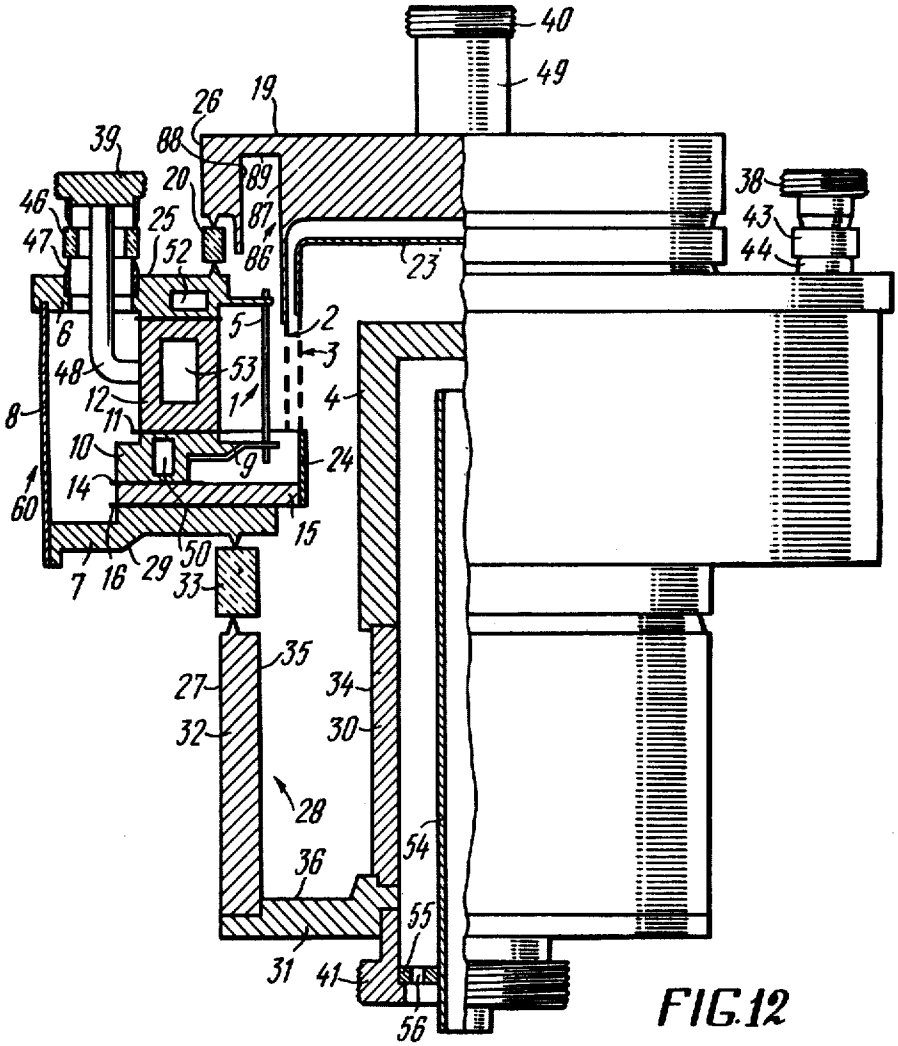

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FIG.12

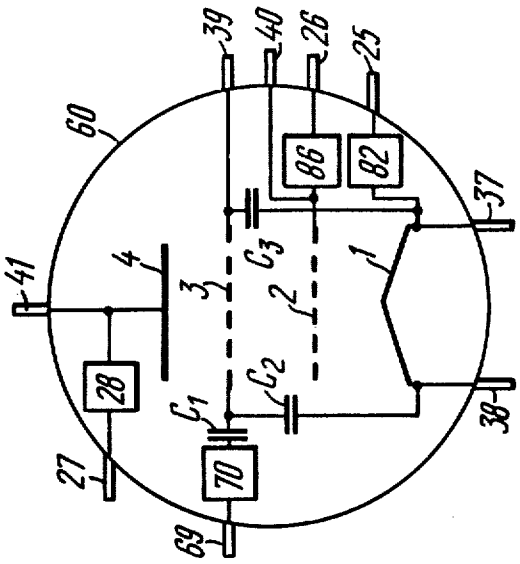

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FIG.14

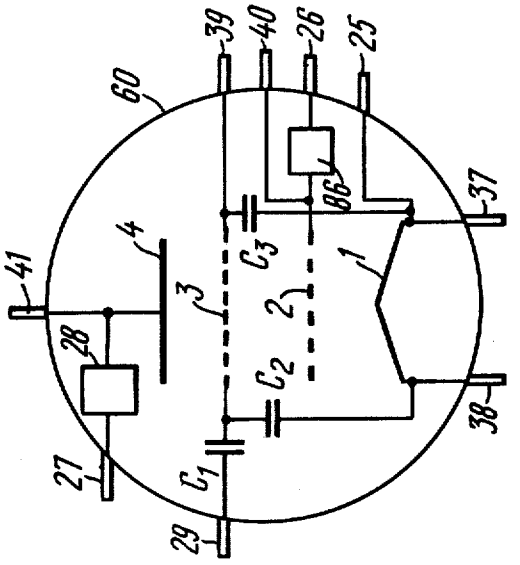

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FIG.13

MICROWAVE ELECTRON TUBE

This is a continuation of application Ser. No. 278,013, filed Aug. 4, 1972 now U.S. Pat. No. 3,805,111.

BACKGROUND OF THE INVENTION

The present invention relates to vacuum tubes, more particularly to grid-controlled microwave electron tubes. The invention can be utilized in microwave power amplifiers operating within a wide frequency band.

An electron tube with oscillatory circuits fully built into the envelope and which displays a low value of equivalent capacitance of the resonators is well-known in the art. This tube, however, can only be used in a frequency range determined by the built-in cavity resonators and the possibility of frequency adjustment is limited. This in turn limits the scope of application of the tube.

There exist microwave electron tubes which contain electrodes - a cathode, an anode and at least one grid, and have an input circuit formed by the cathode and the grid and the associated high-frequency leads, and an output circuit formed by the anode, grid and the associated high-frequency leads.

When such tubes function as microwave power amplifiers, oscillatory systems in the form of coaxial or radial line sections are connected to their high-frequency leads.

A serious disadvantage of such devices is in that large capacitance reflected from the oscillatory systems to the area of the electrodes, the magnitude of this capacitance exceeding by several times the magnitude of the capacitance between these electrodes, especially during operation at frequencies which are above the natural resonant frequency of the device. This markedly reduces the equivalent impedance of the output and input resonators when the device operates within a wide band of amplified frequencies, which fact results in the decreased gain and efficiency of the device.

This disadvantage is caused by the construction of such devices in which the electrodes of the input and output circuits are electrically coupled to their high-frequency leads either directly or through a blocking capacitor.

It is an object of the present invention to provide a new and improved microwave electron tube free of the above disadvantages of well-known tubes.

A further object of the present invention is to provide a new and improved microwave electron tube with maximally reduced value of equivalent capacitance, designed for operation in combination with external oscillatory circuits, which ensures a wide range of operating frequencies.

Another object of the present invention is to provide a new and improved microwave electron tube wherein the electrical coupling of the electrodes with the respective high-frequency leads keeps the value of the capacitance reflected from the external oscillatory systems to the area of the electrodes at a minimum or at least not exceeding the capacitance between these electrodes.

Additionally, it is a further object of the present invention to provide a new and improved microwave electron tube which ensures an increase in the value of the equivalent resistance of the input and output resonators when operating within a wide range of amplified frequencies and which displays high gain and efficiency.

The above and other objects of the present invention are attained in a microwave electron tube wherein at least one of the means for electrical coupling of one of the electrodes to its respective high-frequency lead is accomplished by the use of a section of a microwave line whose first conductor is connected to the electrode and the second, to the high-frequency lead of this electrode, the two conductors being shorted at an end of the section of the microwave line opposite to the points at which these conductors are connected to the electrode and its high-frequency lead. The conductors of the microwave line are constructed in the form of surfaces of revolution the size of which is selected so that the impedance at the points of connection of the conductors to the electrode and its high-frequency lead should be inductive in character.

Such construction of the microwave electron tube described herein ensures a higher power gain and efficiency when signals are amplified within a wide frequency band and enhances the operational reliability of the device as the adjustment for the required operating frequency is carried out at low-heigh frequency currents.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood from the following description of its specific embodiment when read in connection with the accompanying drawings, in which:

FIG. 1 is an axonometric view of a microwave electron tube, according to the invention, with a microwave line section in the output circuit;

FIG. 2 is a general partly sectional view of the device shown in FIG. 1 with a diagrammatic representation of the cathode-grid assembly;

FIG. 3 is a drawing of the device shown in FIG. 1 with a different connection of a microwave line section to the high-frequency anode lead (a general partly sectional representation view with a diagrammatic representation of the cathode-grid assembly);

FIG. 4 is a diagram showing the connection of electrodes to their high-frequency leads in the device shown in FIGS. 1 and 3;

FIG. 5 is a drawing of still another embodiment of a microwave electron tube, according to the invention, with a microwave line section in the output circuit (a general partly sectional view with a diagrammatic representation of the cathode-grid assembly);

FIG. 6 is a diagram showing the connection of electrodes to their high-frequency leads in the microwave electron tube shown in FIG. 5;

FIG. 7 is a diagram showing the connection of electrodes to their high-frequency leads in a microwave electron tube, according to the invention, with microwave line sections provided in circuit and connected to the anode and to the screen-grid;

FIG. 8 is a drawing of a microwave electron tube, according to the invention, with a microwave line section provided in the input circuit and connected to the cathode (a general partly sectional view with a diagrammatic representation of the cathode-grid assembly);

FIG. 9 is a diagram showing the connection of electrodes to their high-frequency leads in the microwave electron tube shown in FIG. 8;

FIG. 10 is a diagram showing the connection of electrodes to their high-frequency leads in the microwave electron tube, according to the invention, with a micro-

wave line section provided in the input circuit and connected to the control grid;

FIG. 11 is a diagram showing the connection electrodes to their high-frequency leads in a microwave electron tube, according to the invention, with microwave line sections provided in the input circuit and connected to the cathode and to the control grid;

FIG. 12 a drawing of a microwave electron tube, according to the invention, which has one microwave line section both in the input and in the output circuits a general partly sectional view with a diagrammatic representation of the cathode-grid assembly);

FIG. 13 is a diagram showing the connection of electrodes to their high-frequency leads in the microwave electron tube shown in FIG. 12;

FIG. 14 is a diagram showing the connection of electrodes to their high-frequency leads in a microwave electron tube, according to the invention, which has two microwave line sections both in the input and in the output circuit.

The microwave electron tube will be described below with respect to a tetrode version with cylindrical electrodes. However, the invention can be also used in triode tubes and in microwave electron tubes with flat electrodes.

The microwave electron tube described herein comprises coaxially disposed electrodes - a cathode **1** (FIGS. 1–14), a control grid **2**, a screen grid **3** and an anode **4**.

The cathode **1** (FIGS. 1 and 2) is made up of a plurality of directly-heated descrete elements **5** uniformly spaced around the cylindrical anode **4** mounted along the longitudinal axis of the device. The cathode elements **5** are equidistant from the surface of the anode **4**, so that the cathode **1** and the anode **4** are coaxial with respect to each other. The upper ends of the cathode elements **5** are attached to an upper flange **6** of the tube casing which also comprises a lower flange **7** and a cylindrical side surface **8**. The lower ends of the cathode elements **5** are attached by means of a resilient member **9** to a flange **10** which is secured on one side to the upper flange **6** of the casing through a mica spacer **11**, a flange **12** and a mica spacer **13** and on the other side to the lower flange **7** through a mica spacer **14**, a flange **15** and a mica spacer **16**.

The control grid **2** (FIG. 1) includes rectangular members **17** which surround the cathode elements **5** and carry wire turns **18** on the side facing the anode **4**. The upper ends of the rectangular members **17** are attached to a flange **19** secured by means of a ceramic insulator **20** to the upper flange **6** of the casing.

The screen grid **3** includes wire turns **21** attached on the edges of rectangular support members **22** which are, in turn, secured to the flange **12** so that the support members **22** form enclosures for the rectangular members **17** of the control grid **2**. The screen grid **3** has a cup-shaped member **23** mounted on the support members **24** and a ring **24** mounted on the flange **15**.

The screen grid **3** is electrically shorted for high frequency currents to the cathode **1** by capacitors, one of which is formed by the flanges **6** and **12** and the interposed mica spacer **13**, and another by the flanges **12** and **10** and the mica spacer **11** and still another by the flanges **10** and **15** and the mica spacer **14**.

The cathode **1** (FIGS. 1 and 2) and the control grid **2** are electrically coupled to their high-frequency leads **25** and **26**, respectively, which are actually the butt surface of the flange **6** and the side surface of the flange **19**.

The cathode **1**, the control grid **2** and their high-frequency leads **25** and **26** form the input circuit of the device now being described.

The anode **4** is electrically coupled to its high-frequency lead **27** by a section of a microwave line **28** while the screen grid **3** is electrically coupled to its high-frequency lead **29** by a capacitor formed by the flange **15**, the flange **7** and the mica spacer **16**.

The anode **4**, the screen grid **3** and their high-frequency leads **27** and **29** form the output circuit of the device according to the invention.

The anode **4** is attached to a hollow cylindrical member **30** mounted on a disc **31** which is, in turn attached to a hollow cylindrical member **32** secured by means of a ceramic insulator **33** to the lower flange **7** of the casing of the device according to the invention.

The microwave line **28** is formed by two conductors **34** and **35**, one of which, **34**, is the outer cylindrical surface of revolution of the cylindrical member **30**, connected to the anode **4**, and the other, **35**, is the inner cylindrical surface of revolution of a cylindrical member **32** and is connected to the high-frequency lead **27** which is the outer cylindrical surface of revolution of the same cylindrical member **32**. The surfaces of revolution which function as the conductors **34** and **35** of the line **28** have circular cross-sections and a constant cross-sectional size along the length of the section of the microwave line **28**. The basis for treating the surfaces of revolution as the conductors **34** and **35** of the line **28** lies in the fact that microwave currents propagate only in an extremely thin skin layer (not more than several microns thick) of the conductive material from which the cylindrical members **30** and **32** are made.

Surfaces of revolution of other types may be likewise used.

The surfaces of revolution which function as the conductors **34** and **35** of the microwave line **28** are disposed coaxially with respect to each other. At the ends opposite to the points at which the conductors **34** and **35** are connected to the anode **4** and to the high-frequency lead **27** these conductors are electrically shorted by a conductive surface **36** of the disc **31**.

The size of the cylindrical surfaces of revolution which function as the conductors **34** and **35** is so selected that at the points at which these conductors are connected to the high-frequency lead **27** the impedance is inductive in character and is commensurate in magnitude with the capacitive reactance between the electrode to which the conductor **34** of the line **28** is connected, in the given embodiment - the anode **4**, and the electrode comprised in the same circuit as the electrode to which the conductor **34** is connected, in the given embodiment the screen-grid **3** comprised in the output circuit which also includes the anode **4**.

Said size of the surfaces of revolution which function as the conductors **34** and **35** of the microwave line **28**, in the given embodiment - the size of the cylindrical surfaces is additionally so selected that the electrical length of the section of the microwave line **28** should be less than 90°, which enables the equivalent capacitance of the section of the microwave line **28** to be reduced.

Besides the size of the surfaces of revolution which function as the conductors **34** and **35** of the microwave line **28**, in the given embodiment - the size of the cylindrical surfaces cisposed coaxially with respect to each other is additionally so selected that the wave impedance of the microwave line **28** at least within the section adjoining the points at which the conductors **34**

and **35** of the microwave line **28** are connected to the electrode and to its high-frequency lead, in the given embodiment - to the anode **4** and to the high-frequency lead **27** of the anode **4,** is not below the capacitive reactance between the electrode to which the conductor **34** of the microwave line **28** is connected, in the given embodiment - the anode **4,** and the other electrode comprised in the same circuit as the electrode to which said conductor **34** is connected, in the given embodiment - the screen grid **3** comprised in the output circuit which also includes the anode **4.**

The size of the surfaces of revolution which function as the conductors **34** and **35** of the microwave line **28** are so selected as to satisfy the inequality:

$$W \geq X,$$

Where

W — the wave impedance of the line **28** over a section adjoining the points at which the conductors **34** and **35** of the line **28** are connected to the electrode and to its high-frequency lead, in the given embodiment - to the anode **4** and to the high-frequency lead 27 (ohms);

X - the capacitive reactance between the anode **4** and the screen grid 3 (ohms) calculated from the formula;

$$X = \frac{1}{2Hf\mathcal{C}},$$

where

f - maximum operating frequency (Hz);

C - the capacitance between the anode **4** and the screen grid **3** (F).

The expressions which relate the size of the surfaces of revolution which function as the conductors **34** and **35** of the line **28,** to the wave impedance of the line **28** are well known to those versed in the art. For the given embodiment wherein the surfaces of revolution have a cylindrical shape and are disposed coaxially with respect to each other the ratios between the diameters of the conductors **34** and **35** of the microwave line **28** are calculated from the formula;

$$\frac{D}{d} = \exp\left(\frac{W}{60}\right),$$

where

D - the diameter of the larger conductor **35** of the line **28;**

d - the diameter of the smaller conductor **34** of the line **28.**

One of the diameters, D or d, is selected so as to suit the structural arrangement of the device. This problem does not concern the essence of the present invention and is quite clear to those versed in the art. The other diameter is selected so as to comply with the calculated diameter ratic D/d.

The length of the section of the microwave line **28** must be such as to comply with the relation:

$$X_1 = kX,$$

where

X_1 — the impedance of the line **28** at the points of connection to the electrode and to its high-frequency lead in the given embodiment - to the anode **4** and to the high-frequency lead 27 (ohms);

X - the capacitive reactance between the anode **4** and the screen grid 3 (ohms);

k - the coefficient which determines commensuration of the X_1 and X.

The coefficient "k" is preferably selected within the limits of 0.5 to 1.5. If the coefficient k is outside these limits the performance of the device will deteriorate in proportion to the deviation of the coefficient k from the limits given above.

The electrical length of the section of the microwave line **28** is calculated from the formula:

$$\theta = \arctan \frac{kX}{W} < 90°,$$

where θ - the electrical length of the section of the microwave line **28** equal to the phase shift occurring in the incident voltage wave as it propagates from the points at which the line **28** is connected to the anode **4** and to its high-frequency lead **27** to the surface **36** of the disc **31** which shorts the line **28,** and equal to the phase shift occurring in the voltage wave reflected from the conductive surface **36** as this wave propagates from the conductive surface **36** to the points at which the line **28** is connected to the anode **4** and to its high-frequency lead **27** (el. degrees).

The expressions which relate the geometrical length of the line section to its electrical length for an arbitrary shape of the surfaces of rotation functioning as the conductors **34** and **35** of the line **28** are well known (See, for example, the book "Theory of Heterogeneous Lines and Their Application in Radio Engineering" by O. N. Litvinenko and V. I. Soshnikov, Moscow, 1964).

Using these expressions the geometrical length of the section of the microwave line **28** can be calculated from its electrical length calculated as above.

For the given embodiment the geometrical length is found from the formula:

$$l = \frac{\theta \cdot \lambda}{360} < \frac{\lambda}{4},$$

where

1 - the geometrical length of the section of the microwave line **28** from the points at which it is connected to the anode **4** and to its high-frequency lead **27** to the conductive surface **36** of the disc **31** (cm);

λ - wavelength corresponding to the operating frequency of the device (cm);

θ - the electrical length of the section of the microwave line **28** (el. degrees).

For example, if the operating frequency f = 1000 MHz (λ = 30 cm) and the capacitance between the anode **4** and the screen grid **3** determined by the construction of the device is equal to **5** pF:

$$X = \frac{1}{2Hf\mathcal{C}} = \frac{1}{2\times3.14\times1000\times10^6\times5\times10^{-12}} = 31.8 \text{ ohms}$$

The wave impedance W of the line **28** is selected so as to satisfy the inequality:

$$W \geq X = 31.8 \text{ ohms},$$

Assume that $W = 50$ ohms.

Now the ratio of the diameters of the surfaces of revolution which function as the conductors **34** and **35** of the line **28** is calculated from the formula:

$$\frac{D}{d} = \exp\left(\frac{W}{60}\right) = \exp\left(\frac{50}{60}\right) = 2.27$$

Suppose one of the diameters, say, diameter d, has to be made equal to **3** cm to suit the construction of the anode. Then the other diameter, D, is calculated as follows:

$$D = d \times 2.27 = 3 \times 2.27 = 6.8 \text{ cm}$$

The coefficient k which is selected within the limits of 0.5 to 1.5 is preferably made close to unity; assuming that $k = 1$. the electrical length is calculated from the formula:

$$\theta = \text{arc tan}\frac{kX}{W} = \text{arc tan}\frac{l \times 31.8}{50} = 32.5° + n\ 180° < 90°$$

where

$$n = 0,1,2,3,4,...$$

To satisfy the inequality assume that $\theta = 32.5°$. Now the geometrical length of the section of the microwave line **28** can be calculated:

$$l = \frac{\theta \times \lambda}{360} = \frac{32.5 \times 30}{360} = 2.7\text{cm} < \frac{30}{4} = 7.5$$

Such arrangement of the output circuit in a microwave electron tube, according to the invention, provides high power gain and high efficiency of the device for a wide band of operating frequencies.

Though the conductors **34** and **35** of the line **28** described above were the cylindrical surfaces of revolution, surfaces of revolution of any other shape may be used just as well to obtain the optimum structural arrangement of the device in various specific cases.

The output circuit of the device, according to the invention, is isolated from its input circuit by means of the cup-shaped member **23** (FIGS. **1** and **2**), the screen grid **3**, the ring **24** and the flange **15.**

The device described herein comprises a means for applying supply voltages to the electrodes, which includes filament leads **37** and **38**, a lead **39** supplying voltage to the screen grid **3**, a lead **40** supplying bias voltage to the control grid **2** and a lead **41** supplying D.C. voltage to the anode **4.** All leads are made in the form of pipe unions. The filament lead **37** (FIG. **1**) is attached by means of a tubular member **42** to the upper flange **6** of the casing. The filament lead **38** is attached to the upper flange **6** of the casing by means of a ceramic insulator **43** secured to a tubular member **44.** The filament lead **38** is connected by two pipes **45** to the flange **10** (the drawing shows one pipe **45**). The lead **39** which supplies voltage to the screen grid **3** is mounted on the upper flange **6** by means of a ceramic insulator **46** and a tubular member **47** attached to each other, and is connected by two pipes **48** to the flange **12** (the drawing shows one pipe **48**). The lead **40** which supplies bias voltage to the control grid **2** is attached to the flange **19** by means of a tubular member **49.** The lead **41** which supplies D.C. voltage to the anode **4** is attached to a disc **31.**

The device, according to the invention, comprises a means for cooling the electrodes, including the two pipes **45** of the filament lead **38** which communicate with a channel **50** in the flange **10** so that one of the pipes serves as an inlet, and the other as an outlet for the liquid cooling the cathodel two pipes **51** of the filament lead **37** which communicate with a channel **52** in the flange **6** so that one of the pipes serves as an inlet, and the other as an outlet for the liquid coolant, two pipes **48** which communicate with a channel **53** in the flange **12** so that one of the pipes serves as an inlet, and the other as an outlet for the liquid cooling the screen grid **3**, a pipe **54** which serves as an inlet for the liquid cooling the anode **4**, the pipe **54** being secured to the lead **41** by means of a washer **55** provided with coolant outlet bores **56** and **57**, a pipe **58** of the lead **40** which serves as an inlet for the liquid cooling the grid **2**, the coolant being discharged through an outlet bore **59** in the lead **40.**

The evacuated envelope **60** of the device, according to the invention, comprises a casing made up of the upper flange **6**, the lower flange **7**, the cylindrical side surface **8**, the flange **19**, the ceramic insulators **20, 33,** 43, 46, the cylindrical member **32**, the disc **31**, the cylindrical member **30**, the anode **4**, the leads **37, 38** and **39**, the pipes **45, 48** and **51** and an exhaust tube **61** used to evacuate the device.

FIG. **3** shows a microwave electron tube similar in construction to the device shown in FIGS. **1** and **2.**

The difference is that in this embodiment the conductor **35** of the line **28** is the inner cylindrical surface of revolution of a hollow cylindrical member **62** connected by an outer conductive cylindrical surface **63** of the cylindrical member **62** with a high-frequency lead **64** of the anode **4**, which is actually the side surface of a disc **65.** A high-frequency lead **66** of the screen grid **3** is the outer surface of a hollow cylindrical member **67** attached at one end to the flange **7** of the casing and at the other end to the disc **65** by means of a ceramic insulator **68.** In this case the evacuated envelope **60** comprises the hollow cylindrical member **67** (FIG. **3**) instead of the hollow member **32** (FIGS. **1** and **2**).

FIG. **4** shows the connection of electrodes to their high-frequency leads in the device described herein (herein-after we will write: "diagrammatically shows the microwave electron tube described herein").

A capacitor C_1 (FIG. **4**) is formed by the flanges **7** and **15** (FIGS. **1-3**) and an interposed mica spacer and serves to decouple the screen grid **3** (FIG. **4**) from its high frequency lead **29** (**66**) for direct current. A capacitor C_2 is formed by the flanges **15** and **17** (FIGS. **1-3**) and the interposed mica spacer **14** and by the flanges **10** and **12** and the interposed mica spacer **11.** A capacitor C_3 (FIG. **4**) is formed by the flanges **6** and **12** (FIGS. **1–3**) and the interposed mica spacer **13.** The capacitors C_2 and C_3 (FIG. **4**) short-circuit the screen grid **3** to the cathode **1** for high-frequency currents.

The foregoing discussion was confined to electric coupling between one of the electrodes, viz. the anode **4** and its high-frequency lead **27** (**64**) accomplished by the use of a section of the microwave line **28.** However, in the microwave electron tube described herein any electrode both in the input and in the output circuits can be coupled to its high-frequency lead by means of a section of a microwave line, or a combination of two or more electrodes can be coupled to the associated high-frequency leads by means of two or more sections of a microwave line.

These embodiments of the invention are discussed in detail below.

FIGS. 5 and 6 show a microwave electron tube, according to the invention, wherein one of the electrodes contained in its output circuit, viz. the screen grid 3, is coupled to its high-frequency lead 69 ny means of a section of a microwave line 70 constructed similarly to the microwave line in the first embodiment of the invention described above. Conductors 71 and 72 of the line 70 (FIG. 5) are the cylindrical surfaces of revolution of hollow cylindrical members 73 and 74, respectively. The conductors 71 and 72 are shorted to each other by a conductive surface 75 of a disc 76.

The conductor 71 of the line 70 is connected to the screen grid 3 by means of a capacitor C_1 (FIG. 6) and a cylindrical member 24 (FIG. 5). The conductor 72 of the line 70 is connected to the high-frequency lead 69 of the screen grid 3 by means of a conductive surface 77 of a cylindrical member 74. In this case an anode 78 is mounted on a disc 79 isolated from the desc 76 by a ceramic insulator 80. A high-frequency lead 81 of the anode 78 is the side surface of the disc 79.

An evacuated envelope 60 of the device comprises the parts 6, 7, 8, 19, 20, 33, 37, 39, 43, 45, 46, 51, 61, 78, 80 as well as the discs 76, 79 and a cylindrical member 73.

FIG. 7 diagrammatically shows the third embodiment of a microwave electron tube described herein, with two sections of the microwave lines 28 and 70 in the output circuit.

In this case the coefficient k which determines the commensuration of the capacitive reactance X between the electrodes of the output circuit and the impedance X_1 of the lines 28 and 70 at the points where they are connected to the electrode and to the high-frequency lead, respectively, is preferably selected within the limits from 0.25 to 0.75.

The embodiments of a microwave electron tube described above make it possible to obtain higher levels of oscillatory power, higher efficiency and higher power gain.

In the fourth embodiment of a microwave electron tube described herein, which is shown in FIGS. 8 and 9, the input circuit has a section of a microwave line 82 constructed similarly to the embodiments described above. One conductor 83 (FIG. 8) of the line 82 is connected to the cathode 1 while the other conductor 84 is connected to the high-frequency lead 25 of the cathode 1. The conductors 83 and 84 are shorted by a conductive surface 85 of the flange 6. The anode 4 is mounted on the disc 79 which is isolated from the lower flange 7 of the casing by a ceramic insulator 33.

FIG. 10 diagrammatically shows still another embodiment of a microwave electron tube described herein, wherein a section of a microwave line 86 in the input circuit electrically couples the control grid 2 with its high-frequency lead 26.

FIG. 11 diagrammatically shows an embodiment of a microwave electron tube described herein with two sections of the microwave lines 82 and 86 in the input circuit of the device.

The embodiments of a microwave electron tube shown in FIGS. 8–11 make it possible to obtain higher power gains.

In the embodiment shown in FIGS. 12 and 13 one section of the microwave lines 28 and 86 is provided both in the input and in the output circuits.

Conductors 87 and 88 of the line 86 are constructed in the form of cylindrical surfaces of revolution shorted by a conductive surface 89 of a flange 19. The conductor 87 is connected to the control grid 2, the conductor 88, to its high-frequency lead 26.

FIG. 14 diagrammatically shows an embodiment of the invention with two sections of the microwave lines 82 and 86 provided in the input circuit and with two sections of the microwave lines 28 and 70 provided in the output circuit.

The embodiments of a microwave electron tube described herein which are shown in FIGS. 12-14 make it possible to obtain a higher level of oscillatory power, a higher efficiency and a higher power gain.

The embodiments of a microwave electron tube shown in FIGS. 8 and 14 are preferably used in microwave power amplifiers connected in a common-cathode circuit.

The operating principle of a microwave electron tube described herein will be discussed in detail with respect to the first embodiment (FIGS. 1-3).

When the device is used in a microwave power amplifier, an input oscillatory system is connected to its high-frequency leads 25 and 26, an output oscillatory system- to the high-frequency leads 27 and 29, a filament source - to the leads 37 and 38, a power supply of the screen grid 3, - to the lead 39, a source of bias voltage for the control grid 2 - to the lead 40, a D.C. supply source of the anode 4 - to the lead 41 (the oscillatory systems and the power sources mentioned above are not shown in the drawing).

The input microwave signal excites the input oscillatory system of the amplifier so that voltage is developed across the grid 2 relative to the cathode 1. This voltage influences the electron stream emitted by the cathode 1, as a result of which the stream is density-modulated at the frequency of the oscillations being amplified. The modulated electron stream passes through the control grid 2 and the screen grid 5 and is collected by the anode 4 and the screen grid 3. This voltage is applied to the high-frequency leads 27 and 29 and to the output oscillatory system-from the side of the anode 4 through the conductors 34 and 35 of the line 28 in the form of surfaces of revolution interconnected by the conductive surface 36 and from the side of the screen grid 3 through the ring 24 and the capacitor C_1.

As the capacitive reactance between the anode 4 and the screen grid 3 is commensurate with the inductive impedance of the microwave line 28 at the points it is connected to the anode 4 and to the high-frequency lead 27, the microwave voltage between these electrodes and the microwave voltage at said points of the line 28 are close in value, whereas the microwave voltage between the high-frequency leads 27 and 29, which is the difference between the two voltages mentioned above, is low.

From the oscillatory system the microwave voltage is applied to the load (not shown in the drawing) coupled to this system and the load develops useful microwave power. The load impedance found in the area of the electrodes, viz., the anode 4 and the screen grid 3, i.e. the equivalent load impedance determines the magnitude of the useful microwave power at the load, the efficiency and the power gain, which are the larger, the higher is the equivalent load impedance. However, when the microwave power amplifier operates within a wide frequency band, the equivalent load impedance is inversely proportional to the equivalent capacitance of the output oscillatory system found in the area of the anode 4 and thes screen grid 3. This equivalent capacitance is made up of the following three components:

the capacitance between the anode **4** and the screen grid **3**, the equivalent capacitance of the section of the microwave line **28** and the capacitance reflected to the area of the anode **4** and the screen grid **3** from the output oscillatory system connected to the high-frequency leads **27** and **29**.

A distinctive feature of a microwave electron tube, according to the invention, is that the capacitance reflected from the output oscillatory system to the area where the electrodes are located is only a fraction of such capacitance in a device wherein the electrode is connected with its high-frequency lead without the use of a microwave line section having conductors whose length has been selected in accordance with the relations given above.

Since the capacitance reflected from the oscillatory system to the area where the electrodes are located decreases in proportion to the square of the ratio of the voltage across the high-frequency leads **27** and **29** to the voltage between the anode **4** and the screen grid **3**, which is rather small, this capacitance does not exceed a fraction of the capacitance between these electrodes. Therefore the equivalent capacitance of the output oscillatory system is determined in the main by the capacitance between the anode **4** and the screen grid **3** and by the equivalent capacitance of the section of the microwave line **28**, which, provided the length of the conductors **34** and **35** of the line **28** has been selected in accordance with the above relations, does not exceed 28.3 percent of the capacitance between the anode **4** and the screen grid **3**.

The marked decrease of the equivalent capacitance of the oscillatory system in a microwave electron tube described herein as compared to the devices wherein the invention has not been provided ensures a higher equivalent load impedance and, consequently, a higher useful power at the load, a higher efficiency and a higher power gain.

Besides, the efficiency of the oscillatory systems and the reliabilty of the device are also improved in view of the fact that the microwave voltage at the high-frequency leads **27** and **29** and, consequently, at the ceramic insulator **33** and high-frequency currents in the oscillatory system are low.

A microwave electron tube, according to the invention, whose embodiments are shown in FIGS. **5–14** operates similarly to the first embodiment which was described above. The difference is that in the embodiment of the invention shown in FIGS. **8–11** the input oscillatory circuit has a greater equivalent impedance found in the area of the cathode **1** and the control grid **2**, while in the embodiments shown in FIGS. **12-14** both the equivalent impedance and the equivalent load impedance are greater.

A microwave electron tube described herein have escential advantages over a similar device used as a prototype with respect to a number of performance characteristics, viz., the efficiency and, especially, the power gain. The effectiveness of the invention rises with higher operating frequencies of the device: at a frequency of 500 MHz the power gain increases 21 times.

Besides, the use of the device, according to the invention, in microwave power amplifiers considerably enhances their reliability.

What is claimed is:

1. A microwave electron tube comprising: a plurality of electrodes including at least a first electrode, a second electrode arranged opposite said first electrode and at least one grid arranged between said first and second electrodes; high-frequency leads for each of said electrodes; means for electrically coupling each of said electrodes to its high-frequency lead, at least one of said means coupling one of said electrodes being constructed in the form of a section of a microwave line; a first conductor of said section of the microwave line being connected at one end to said one electrode; a second conductor of said section of the microwave line being connected at one end to the high-frequency lead of said one electrode, the other ends of said first and second conductors being electrically shorted, said first and second conductors being constructed in the form of surface of revolution whose size is selected so that the impedance at said point of connection is inductive in character; means for feeding supply voltages to said electrodes, and an evacuated envelope means enclosing said electrodes and said section of the microwave line.

2. A microwave electron tube as claimed in claim **1**, wherein said surfaces of revolution made up by said first and second conductors are arranged coaxially relative to each other.

3. A microwave electron tube as claimed in claim **1**, wherein the electrical length of said section of the microwave line is less than 90°, which ensures the inductive character of the impedance at said points of connection.

4. A microwave electron tube as claimed in claim **3**, wherein said surfaces of revolution have a constant crosssectional size along with length of said microwave line section and the length of said microwave line section is less than a quarter of a wavelength corresponding to the operating frequency of the tube.

5. A microwave electron tube as claimed in claim **4**, wherein said surfaces of revolution made up by said first and second conductors are arranged coaxially relative to each other.

6. A microwave electron tube comprising: a plurality of electrodes including at least a first electrode, a second electrode arranged opposite said first electrode and at least one grid arranged between said first and second electrodes; high-frequency leads for each of said electrodes, said first electrode, said grid and the high-frequency leads thereof defining an input circuit of said tube; said second electrode, said grid and the high-frequency leads thereof defining an output circuit of said tube; means electrically connecting each of said electrodes to its respective high-frequency lead; at least one of said means coupling one of said electrodes being constructed in the form of a section of a microwave line; a first conductor of said section of the microwave line being connected at one end to said one electrode; a second conductor of said section of the microwave line being connected at one end to the high-frequency lead of said one electrode, the other ends of said first and second conductors being electrically shorted, said first and second conductors being constructed in the form of surfaces of revolution whose size is selected so that at said points of connection the impedance is inductive in character and commensurable in magnitude with a capacitive reactance between said one electrode and an adjacent electrode of the same circuit of which said one electrode forms a parts connected to said conductor and so that the value of the wave drag of said section of the microwave line, at least across that portion thereof near said points of connection, is not less than said value of said capacitive reactance; means for feeding supply voltages to said electrodes, and an evac-

uated envelope means enclosing said electrodes and said section of the microwave line.

7. A microwave electron tube as claimed in claim 6, wherein said surfaces of revolution formed by said first and second conductors are arranged coaxially relative to each other.

8. A microwave electron tube as claimed in claim 6, wherein the electrical length of said section of the microwave line is less than 90°, which ensures the inductive character of impedance at said points of connection.

9. A microwave electron tube as claimed in claim 8, wherein said surfaces of revolution have a constant crosssectional size along said length of said microwave line section said length of said microwave line section being less than a quarter of a wavelength corresponding to the operating frequency of said microwave electron tube.

10. A microwave electron tube as claimed in claim 9, wherein said surfaces of revolution formed by said first and second conductors are arranged coaxially relative to each other.

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