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Hopper, Jr.

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[54] **TEMPERATURE STABILIZED COAXIAL CAVITY MICROWAVE OSCILLATOR**

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[51] **Int. Cl.**[2] **H03B 5/04**; H03B 5/18

[58] **Field of Search** 331/97, 98, 101, 176

[56] **References Cited**

UNITED STATES PATENTS

2,436,700	2/1948	Spielman	331/101 X
3,631,363	12/1971	Miller	331/97

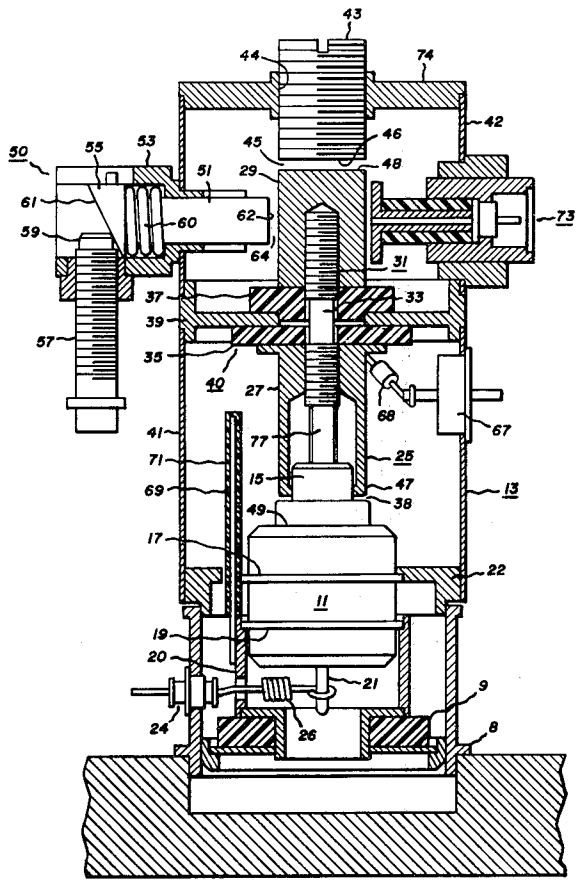
Primary Examiner—Siegfried H. Grimm

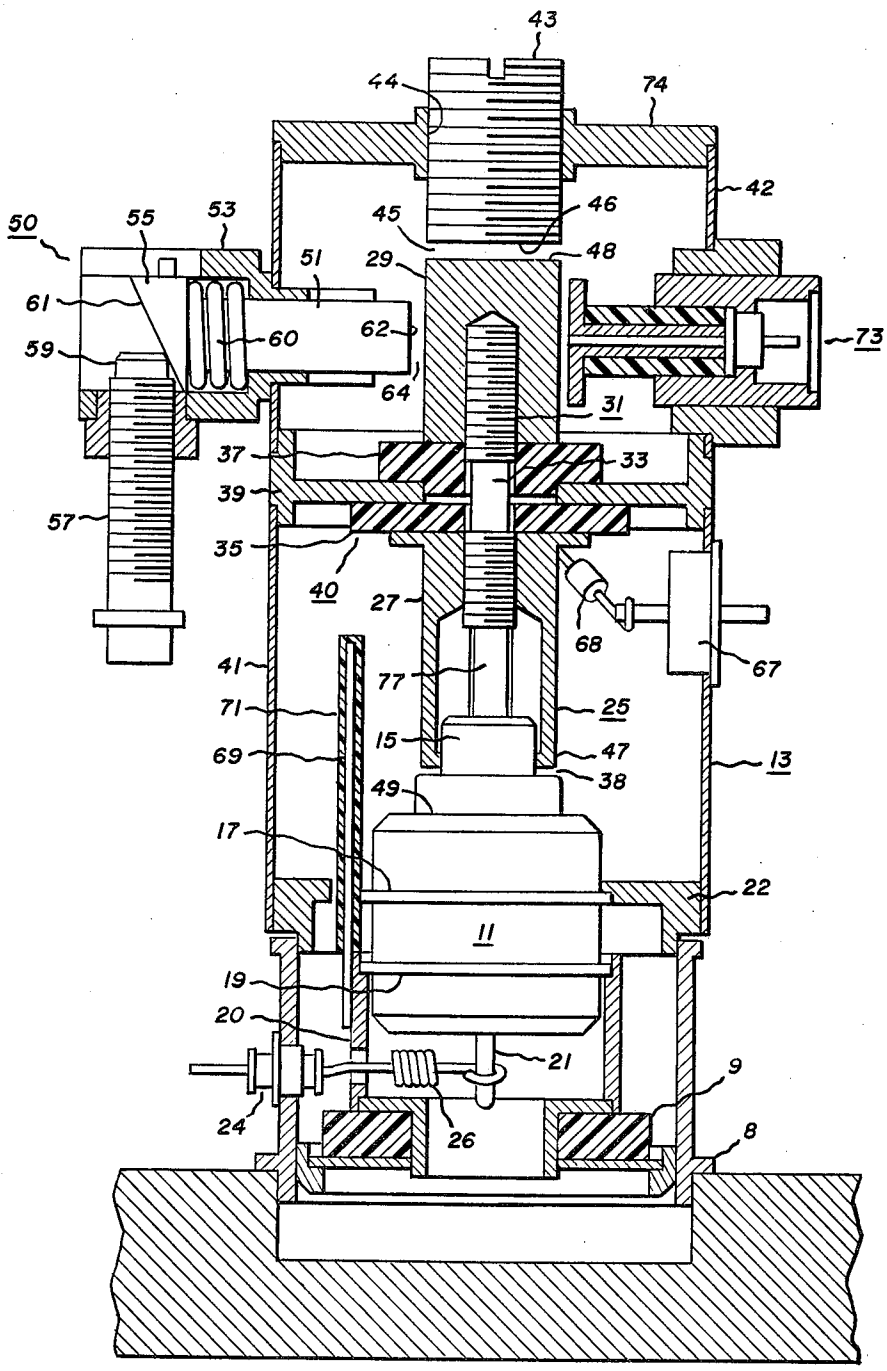
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[57] **ABSTRACT**

A microwave, one-half wave, coaxial cavity oscillator comprising a tubular cavity body having a section thereof constructed of a material having a high coefficient of expansion, a tube, an anode line having a section thereof constructed of a material having a low coefficient of expansion, and tuning member connected to an end plate of said body remote from said tube, which member forms an automatically variable capacitor with an end face of the anode line thereby to provide a variable capacitance responsive to operating temperature variations to minimize frequency deviations when the oscillator is operated under widely varying ambient temperatures. Another feature of the oscillator comprises a partition of high thermal conductivity connected between the anode line and cavity body to rapidly dissipate the heat generated by the tube, thereby to minimize the temperature gradient within the cavity body.

9 Claims, 1 Drawing Figure




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TEMPERATURE STABILIZED COAXIAL CAVITY MICROWAVE OSCILLATOR

BACKGROUND OF THE INVENTION

This invention relates to microwave cavity oscillators and, more particularly, to one-half wave, microwave oscillators having means for providing a stable resonant frequency over widely varying operating temperatures.

As is well known, in the operation of a microwave cavity oscillator, changes in the operating temperature of the oscillator cause an inverse variation in the resonant frequency of oscillation. This phenomenon has been explained as being due, in large part, to changes in the interelectrode spacings of the oscillator tube responsive to operating temperature changes. Because of the close spacing of the electrodes of the tube, small, absolute dimensional changes in the spacing cause relatively large changes in the capacitance of the oscillator circuit and thus relatively large changes in the resonant frequency.

One approach to this problem is represented by U.S. Pat. No. **2,436,700** which describes a quarterwave cavity oscillator having an anode line and a quarterwave choke connected to one end of the line for terminating the cavity, which line and choke are constructed of a material having a high coefficient of expansion, and a cavity body which is constructed of a material having a low coefficient of expansion. This construction results in the electrical length of the cavity varying in response to operating temperature variations, which length variations will offset the frequency deviations normally caused by the operating temperature variations. This approach, as will be appreciated by those skilled in the art, provides no suggestion as to the solution to this problem in a one-half wave cavity oscillator.

Another approach to this problem is represented by U.S. Pat. No. **3,173,106**, which describes bimetallic strips, mounted on the grid sleeve, for automatically varying the capacitance in the anode-grid cavity and thereby offsetting frequency deviations caused by variations in the operating temperature of the oscillator. This approach has been found to be unacceptable because of the difficulty incurred in accurately setting the bimetallic members and thereafter assembling them in the composite oscillator body. The strips have also been found to be sometimes unreliable over the life of the oscillator due to problems caused by the extreme operating conditions to which the oscillators are sometimes subjected, such as severe shock and vibration.

Accordingly, it is an object of this invention to provide an improved one-half wave cavity oscillator which has a substantially stable frequency over widely varying operating temperatures.

Another object of this invention is to provide a compensating element which is accurate, reliable, and easily adjusted from the exterior of the cavity.

SUMMARY OF THE INVENTION

The objects of the invention are accomplished by a microwave, one-half wave cavity oscillator comprising: a tubular cavity body; a tube mounted at a first end of said body; an anode line connected to the anode of the tube; an electrically conductive member connected to the other end of said body, said member forming a variable capacitor with the end of said anode line; and said body and said line comprising means for controlling the spacing of said capacitor automatically in response to variations in the operating temperature, thereby to offset the frequency deviations normally caused by said operating temperature variations.

Another feature of the oscillator of this invention is a partition of a high thermal conductivity connected between the anode line and the cavity body to rapidly dissipate the heat generated by the tube, thereby to minimize temperature gradients with the cavity body.

The invention and the advantages thereof will be apparent from a consideration of the following description taken in conjunction with the accompanying claims.

DESCRIPTION OF THE DRAWING

The drawing is a longitudinal, cross-sectional view of a cavity oscillator constructed in accordance with the invention herein.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the drawing, an axial, cross-sectional view of a one-half wave, grid-separation, microwave oscillator is shown. In accordance with the invention herein, the oscillator is designed to minimize the frequency shift when the oscillator is operated under widely varying operating temperature, which can be due to either (1) heat internally generated by the tube, or (2) changes in the ambient temperature which can vary between −54°C to +100°C, or both.

As shown in the drawing, the oscillator comprises a microwave tube **11** which may be a conventional ceramic planar triode such as General Electric Type No. Y-**1636** and a microwave cavity **13** which is generally in the form of a cylindrical, tubular body. The tube **11** is mounted with the principal electrodes thereof disposed in a plane perpendicular to the major axis of the cylindrical cavity **13**. The triode tube **11**, as is well known, consists of anode, grid, and cathode (all not shown). The terminals for the anode, the grid, and the cathode are respectively indicated at **15, 17,** and **19.** The tube **11** is also provided with a heater (not shown), having a pair of heater pins connected thereto (one of which is shown at **21**). Power is supplied to the heater in a conventional manner via a feedthrough capacitor and a choke coil connected to each heater pin, the capacitor and coil for pin **21** being shown at **24** and **26,** respectively.

As is conventional in the construction of a grid-separation oscillator, the oscillator consists of two tunable sections of the coaxial line type. The first, a cathode-grid cavity, is formed by (1) a cathode sleeve **20** connected to cathode terminal **19,** (2) a grid plate **22** connected between the grid terminal **17** and the cavity body **13,** and (3) the cavity body **13.** The cathode sleeve **20** is supported in and electrically insulated from the cavity body **13** by a washer **9** of a thermally conductive and electrically insulative material, such as beryllia, which washer is fixed to the inner wall of body **13.** The washer **9** provides a thermally conductive path for transmitting heat from the cathode region of the oscillator to a heat-sinking base **8.**

The second cavity, a grid-anode cavity, is formed by an anode line **25,** which is connected to the anode terminal **15** of tube **11,** and the cavity body **13.** The operating frequency of the cavity is largely determined in a gross manner by the dimensions of the cavity and the length of the anode line **25.** Thus, for a given length of

anode line 25, which is designed to be one-half wavelength at the operating frequency, the gross operating frequency will be that for which the anode line 25 is one-half wavelength. Unwanted variations in the operating temperature will tend to change this frequency.

Accordingly, an essential feature of this invention is to maintain the electrical length of anode line 25 essentially constant over widely varying operating temperature ranges, thereby to achieve frequency stability. This, as explained in detail hereinbelow, is accomplished primarily in two ways: (1) by providing a short and effective thermally conductive path to transmit the internally generated heat of the tube from the anode line 25 to the cavity body 13, thereby to minimize thermal expansion of the cavity components; and (2) by providing a structural design which minimizes the effect of any thermal expansion of the components on the electrical characteristics of the cavity.

The anode line 25 is comprised of a first line section 27, a second line section 29, which are joined by a threaded connector 31. At one end, first line section 27, which is made of a material having a high thermal conductivity such as brass, has a plurality of spring fingers 47 which form a snuggly fitting, slidable connection around the perimeter of the anode terminal or stud 15. The other end of line section 27 is provided with a threaded recess for receiving one end of connector 31. The connector 31 is provided with a smooth, unthreaded portion 33 which is adapted to be disposed within a circular central aperture formed in a washer 35, which is preferably of high thermally conductive, electrically insulative material such as beryllia. The smooth portion 33 of the connector 31 is similarly disposed within a circular central aperture of a second washer 37, which may be made of any conventional ceramic. An apertured central body section 39, which at its outer peripheral surface is fixedly connected to the cavity body 13 such as by brazing, is sandwiched between the adjacent faces of washers 35 and 37.

The central body section 39, the washer 35, and the washer 37 combine to form a partition 40 which (1) divides the cavity body 13 into first and second body sections 41, 42, and (2) serves to partially thermally isolate the first and second line sections 27, 29, respectively, disposed therein. The first body section 41 is preferably constructed of a material having a low coefficient of expansion, such an Invar. Thus, as to the first way noted above, it will be clear that during the operation of the tube 11, the heat generated at the anode is effectively conducted through the line section 27 and the beryllia washer 35 to the central body section 39, and thence to the wall of the cavity 13 where it is effectively dissipated and, therefore, minimizing the undesired elongation of the line sections 27, 29.

As to the second way, to mitigate changes in the effective electrical length of the anode stud 15 and line section 27, which together extend between the active anode surface or face within the tube 11 and central body section 39, over a relatively wide swing of operating temperatures, the present invention provides that the first body section 41 is preferably made of a low temperature coefficient of expansion material, such as Invar. As a result, the dimensional changes of this portion of the cavity will be minimal through such operating temperature variations. As has been stated, the first line section 27 is preferably made of brass for its electrical and thermal conducting properties and thus the section 27 must unavoidably have a high thermal coefficient of expansion. However, because one end of line section 27 is longitudinally fixed by central body section 39 and the other end of line section 27 is slidably adjustable on anode stud 15, any thermal, longitudinal, dimensional change of anode stud 15 and line section 27 is accommodated within free spaces 38, 77 provided between the end of spring fingers 47 and the end of a ceramic insulator 49 and between the end of anode 15 and the adjacent end of connector 31, respectively, without affecting the combined effective electrical length of anode stud 15 and line section 27. For example, for an increase in temperature, the Invar material of first body section 41 expands only minimally, whereas the brass material of the line section 27 and anode stud 15 will expand but will merely expand into the free spaces 38, 77, and the combined effective electrical length of the anode stud 15 and line section 27 is thus only affected by the increase in the length of the Invar body section 41.

Additionally, considering the composite anode line 25, the second section 29 of anode line 25 is preferably made from a low coefficient of thermal expansion material, such as Invar. The small dimensional variation with variable temperatures of second line section 29, and the stable electrical length of anode stud 15 and line section 27 provided by the sliding contact fingers 49 and the stable center section 39, as explained above, all combine to keep the effective electrical length of the half-wave line substantially constant.

As has been explained hereinabove, due to the variation in the interelectrode capacitances of the tube 11, the frequency of oscillation will vary inversely with the operating temperature of the tube. A second feature of the invention which acts to minimize this frequency variation resides in the construction of the top section of the cavity which comprises the second body section 42, an end plate 74, and a tuning screw or member 43. The body section 42 and the end plate 74 are made from a high thermal conductivity and relatively high thermal expansion material, such as brass, and the tuning screw 43 is made from a low thermal expansion material, such as Invar. The tuning screw 43 is threaded through a central aperture 44 in the end plate 74 such that an end face 46 is disposed opposite to and spaced from an end surface 48 of the second line section 29, thereby to functionally form a variable capacitor or loading gap 45 therebetween.

The second line section 29 of anode line 25 is also made of Invar or other low temperature coefficient of expansion material. As a result, when the portion of the cavity remote from the tube experiences relatively wide operating temperature variations, a corresponding dimensional change will be experienced because the second body section 42 is made of a relatively high coefficient of expansion material. This causes end surface 46 of Invar tuning screw 43 to be moved toward and away from the end face 48 of second line section 29 with the result that the loading gap 45 will be increased for an increase in temperature or decreased for a decrease in temperature. Accordingly, the variations in the loading gap width cause variations in capacitance of the loading, which variations in capacitance cause an inverse variation in the frequency of operation. For example, for an increase in temperature, the gap width is correspondingly increased with a reduction in capacitance and a corresponding increase in the frequency. This in-

crease in frequency compensates for the decrease in frequency which is normally experienced by an oscillator cavity subject to an increase in the operating temperature.

A further feature of this invention is found in a vernier tuner **50.** As shown, the vernier tuner **50** comprises a cylindrical tuning element **51,** which is slidingly disposed within a sleeve **53** which, in turn, is fixedly mounted to an aperture in the second body section **42.** The portion of the sleeve **53** external to body section **42** is formed with an enlarged diameter portion which encloses a cam **55** formed on the external end of tuning element **51.** The cam **55** is biased outwardly by a coil spring **60** to cooperate with a screw **57,** a contacting end **59** of the screw **57** bearing against a tapered surface **61** of the cam **55.** It will be apparent that the movement of the screw inwardly of the enlarged portion tends to move the cylindrical member **51** inwardly of the cavity, reducing a gap **64** formed between free end **62** of the tuning element **51** and the adjacent side wall of the second line section **29.** As the gap **64** is decreased, the operating frequency is lowered. Conversely, increasing the gap **64** will raise the frequency.

The tuner **50** is designed so as to be relatively nonresponsive to operating temperature changes. This is accomplished by constructing tuning element **51** and screw **57** of low coefficient of expansion material such as Invar; and because line section **29** is also of low coefficient of expansion material, the width of gap **64** remains relatively unchanged over relatively wide operating temperature variations. The sleeve **53** can be constructed of any electrically conductive material such as brass without substantially affecting the stability of tuner **50.**

In practice, the operating frequency should be approximately **8–10** percent above the desired operating frequency when tuning screw **43** is removed and when the gap **64** between tuning rod **51** and line section **29** is maximum. The amount of compensation provided for temperature variations can be controlled by varying ratio of frequency reduction provided by tuning screw **43** to that provided by tuner **50.** The proper ratio for the settings of the tuner **50** and tuning screw **43** is empirically determined. As is apparent, the tuner **50** provides a substantially constant loading effect on line **25** with operating temperature variations, while the loading effect of tuning screw **43** varies from a predetermined initial setting with the instantaneous operating temperature to provide an essentially constant frequency.

The operation of a grid-separation oscillator is well known to those skilled in the art and will not be discussed in detail herein.

In accordance with well known techniques, DC anode voltage to the anode line **25** is provided to preferably the quarter wave point of the anode line **25** via a feed-through capacitor **67** and an RF choke **68,** both of which being of conventional construction. When the tube is biased conductive and the cathode is connected to ground via means (not shown), conduction will begin and generate an output signal, a portion of which is coupled back to the cathode-grid cavity as regenerative feedback via a conventional feedback finger **69** encased in an insulator **71** so as to increase the conductivity of the tube to saturation. A conventional capacitive, or other well known type, output probe **73** is provided in an aperture of the second body portion **42** to couple energy out of the anode-grid cavity.

It has been found that oscillators constructed in accordance with the invention herein, when operated in a pulsed mode, are very effective in maintaining a stable operating frequency under widely varying ambient temperature conditions. For example, such oscillators, when operated (**1**) at a specified "L" band operating frequency, (**2**) for a pulse duty cycle of between **0.01** to **0.10** percent, (**3**) over an ambient temperature variation between **−54°C** to **+70°C,** and (**4**) in conjunction with an amplifier providing **20** db. isolation, provide a maximum frequency deviation of between **±5** MHz.

While the invention has been shown and described with respect to a preferred embodiment of a one-half wave grid separation microwave cavity oscillator, it is not intended to be limited to a particular type of oscillator or a particular form thereof. Accordingly, the appended claims are intended to cover all modifications within the spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A microwave one-half wave cavity oscillator comprising:

a. a tubular cavity body;

b. a controlled charge carrier device mounted at a first end of said body, said device comprising a first electrode terminal;

c. a conductive line connected to said terminal, said line extending coaxially of the longitudinal axis of said body and forming a coaxial one-half wave resonant cavity with said body, said line having a surface adjacent the second end of said body and transverse to said axis;

d. an electrically conductive member connected to said body and having a face disposed opposite to and spaced from said surface thereby to form a capacitive relationship between said face and said surface;

e. said body and said line comprising means varying the spacing between said face and said surface responsive to operating temperature variations, thereby to minimize frequency deviations caused by operating temperature variations.

2. The oscillator of claim **1** wherein said means is

a body section of said body constructed of a material having a high coefficient of expansion, and

a line section of said line constructed of a material having a low coefficient of expansion, and

whereby the spacing variation is approximately directly proportional to the ambient temperature variation.

3. The oscillator of claim **1** wherein said body comprises a first body section of a material having a low coefficient of expansion;

said line comprises a first line section of a high thermal conductivity and a high coefficient of expansion, said first line section disposed within said first body section;

said connection between said line and said terminal comprises a first end of said first line section slidably mounted on said terminal; and

said oscillator comprises a partition connected to said first line section and to said body, for holding the electrical length of said first line section substantially constant during variations in the ambient temperature.

4. The oscillator of claim 3 wherein said means is
a second body section connected to said first body section and constructed of a material having a high coefficient of expansion and
a second line section connected at a first end to a second end of said first line section and constructed of a material having a low coefficient of expansion, said surface being formed on one end of said second line section whereby the spacing variation is approximately directly proportional to the ambient temperature variation.

5. The oscillator of claim 4 wherein said partition has a high thermal conductivity and is disposed between said first and second body sections.

6. The oscillator of claim 5 wherein said partition comprises
an electrically insulating washer thermally connected to said first line section and constructed of a thermally conductive material, and
a central body section thermally connected between said body and said washer.

7. The oscillator of claim 1 further comprising an end plate closing the second end of said body and wherein said member is a tuning screw mounted in said end plate.

8. The oscillator of claim 1 further comprising an oscillator tuning element having an end surface disposed in a substantially parallel relationship to said axis, said element forming a capacitive relationship with said line and being constructed of a material having a low coefficient of thermal expansion.

9. The oscillator of claim 1 wherein said device is a triode vacuum tube and said terminal is connected to the anode of said tube.

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