

- [54] **COAXIAL CAVITY RESONATOR WITH
SEPARATE CONTROLS FOR
FREQUENCY TUNING AND FOR
TEMPERATURE COEFFICIENT OF
RESONANT FREQUENCY
ADJUSTMENT**

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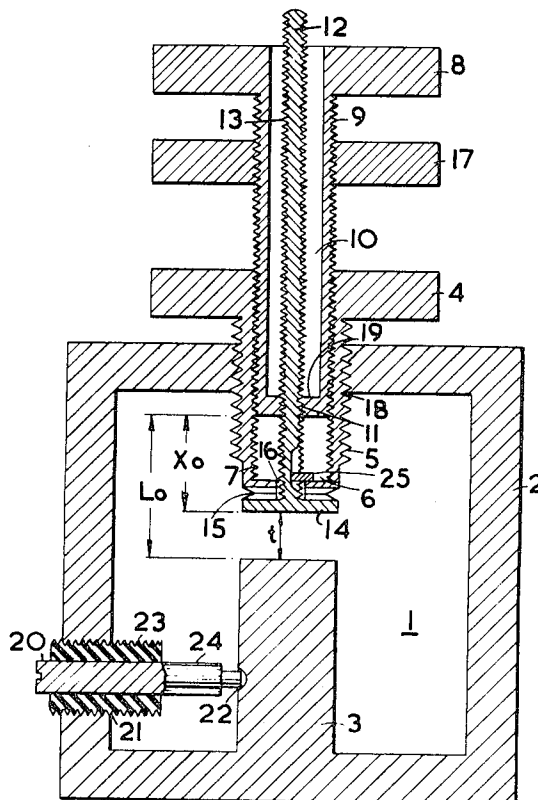
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[57] **ABSTRACT**

A temperature compensated tuning apparatus for a co-axial resonant cavity comprises a telescopic tuning member having a first section and a second section, the sections having different co-efficients of thermal expansion and being connected by a co-efficient of expansion adjusting screw which has an internally threaded bore engaged with the first section and an externally threaded part engaged with the second section; a capacitive disc mounted co-axially on the end of the first section within the cavity is maintained in electrical contact with the second section by means of resilient contact members while permitting a telescopic relative motion of the first section with respect to the second section. The first member is made of an alloy of 36 percent nickel and 64 percent iron while the second member and the co-efficient expansion screw are made of brass or copper. The arrangement provides a cavity having an adjustable positive thermal co-efficient of resonant frequency which is useful for compensating for the negative co-efficient of frequency of a Gunn diode oscillator.

4 Claims, 1 Drawing Figure



COAXIAL CAVITY RESONATOR WITH SEPARATE CONTROLS FOR FREQUENCY TUNING AND FOR TEMPERATURE COEFFICIENT OF RESONANT FREQUENCY ADJUSTMENT

BACKGROUND OF THE INVENTION

The present invention relates to tuning mechanisms for waveguide structures, particularly applicable to resonant cavities of the coaxial type, which may be used in microwave engineering apparatus for generating or for operating on high frequency electromagnetic waves. Particularly, but not exclusively, the present invention relates to coaxial resonant cavities in which a Gunn diode is used to provide a microwave generator.

In known microwave generators using a Gunn diode mounted in a coaxial resonant cavity, it is difficult to maintain the frequency of the generator constant with varying temperature, because Gunn diodes exhibit large negative frequency/temperature coefficients and there is wide random variation between diodes when mounted in typical resonant cavities. Gunn diodes, as presently produced, exhibit frequency/temperature coefficients in the range 0.5 to 2.5 MHz/°C when operated in typical resonant cavities as microwave generators at X-band frequencies (8 to 12 GHz). Because of the large value and range of negative frequency/temperature coefficients, compensating circuitry which may be quite complicated, often has to be incorporated in the oscillator circuit.

An object of the present invention is to provide a tuning mechanism for a coaxial resonant including a mechanism for producing an adjustable positive frequency/temperature coefficient, to compensate for the temperature dependence of typical Gunn diodes.

SUMMARY OF THE INVENTION

According to the present invention there is provided a tuning mechanism for a waveguide structure comprising a telescopic tuning member having a first section and a second section and each made of a material having a different coefficient of thermal expansion to that of the other, connected by a temperature coefficient adjustment screw having a first threaded part engaged with screw thread on the first section and a second threaded part engaged with a screw thread on the second section; and contact means disposed to make an electrical contact, or an effective short-circuit at the operating frequency of the waveguide structure, between the surfaces of the first section and the second section which will be required to act as current-carrying surfaces within the waveguide structure, while permitting a telescopic relative motion of the first section with respect to the second section.

The waveguide structure may be an electromagnetically resonant cavity.

The contact means may comprise a contact member attached to one of the sections of the tuning member and having a set of resilient contact fingers making contacts to the other section. Alternatively, it may be a separate part having two sets of resilient contact fingers making contact to the first section and the second section respectively. It may be possible, in some applications of the invention, to use some form of choke-coupled non-contacting arrangement in place of a set of contact fingers, but at the operating frequencies of most Gunn diode oscillator circuits this alternative will probably be impractical.

One section of the tuning member and the structure in which it is to be used may conveniently be made of brass or copper while the other section may be made of a metal of comparatively low thermal expansion, for instance the 36 percent nickel 64 percent iron alloy known as "INVAR" (Registered Trade Mark). The temperature-coefficient adjusting screw may also conveniently be of brass. A mechanical key or similar arrangement should be provided to prevent rotation of the second section relative to the first section.

BRIEF DESCRIPTION OF THE DRAWING

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawing which is a sectional view of a coaxial resonant cavity utilizing the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A coaxial resonant cavity 1 comprises a metal block 2 and a metal post 3 one end of which is electrically connected to the block 2. The block 2 has a threaded hole 18 through a face opposite to and in axial alignment with the post 3. An externally threaded tuning screw 4 having an external thread 5, an internal bore 6 and an internal screw thread 7 is screwed into the hole 18. An adjusting screw 8, for adjusting the frequency/temperature coefficient, has an external thread 9 which matches and engages the thread 7 on the tuning screw 4, and an internal bore 10 which has a step 19 at its lower end. The step 19 has, at its center, a threaded hole 11 whose thread has the same pitch as the external thread 9 of the adjusting screw 8. All the aforementioned parts are made of brass or a similar material. A plunger comprises a stem 12 and a disc 14 both of which are made of the 36 percent nickel 64 percent iron alloy known as "INVAR" (Registered Trade Mark), the stem 12 having a screw thread 13 along its length. The screw thread 13 matches and engages the screw thread of the hole 11 in the adjusting screw 8. The tuning screw 4, the adjusting screw 8 and the plunger stem 12 and its disc 14 are all coaxial. A hole 16 in the base of the tuning screw 4 allows clearance for the stem 12. The diameter of the internal bore 10 of the adjusting screw 8 similarly provides clearance around the stem 12 except at the step 19. A locknut 17 is engaged with the thread 9 and may be tightened against the tuning screw 4 to prevent unintentional adjustment of the adjusting screw 8. A contact spring 15 is provided between the base of the tuning screw 4 and the back of the disc 14 to take up any backlash in the engagement of the threads 11 and 13 and to provide a low-impedance path for radio frequency currents between the disc 14 and the tuning screw 4. A key 25 protrudes from the end of the tuning screw 4 into a keyway cut longitudinally in the stem 12 to prevent the plunger 12, 14 from rotating when the adjustment screw 8 is rotated, while allowing movement of the plunger 12, 14 with respect to the tuning screw 4. A Gunn diode 24 attached in a suitable manner to a metal mounting member 20 contacts the post 3 at a predetermined distance from the top face of the post 3. The mounting member is surrounded by an electrically insulating sheath 23 which is externally threaded. The whole assembly is screwed into a hole 21 in the block 2. A locating hole 22 in the post 3 is used to locate one end of the Gunn

diode 24. Electrical connections (not shown) to the Gunn diode 24 are conveniently made through the metal mounting member 20 and the metal block 2 of the cavity 1. A coaxial output connection (not shown) is provided to draw electromagnetic energy from the cavity 1.

In operation, the component parts are assembled as shown in the drawing and the tuning screw 4 is adjusted to produce the required resonant frequency of the cavity. This frequency is determined in part by the geometry of the cavity 1 and the post 3, by the capacitance between the lower face of the disc 14 and the top face of the post 3 and by the effective capacitance of the Gunn diode 24. Electrically, a Gunn diode may be regarded as a capacitance in parallel with an oscillator and the electrical equivalent circuit of the resonant cavity and Gunn diode may be regarded as a parallel tuned circuit comprising an inductance, due to the post 3, a capacitance, due to the gap t between the disc 14 and the post 3, and another capacitance due to the Gunn diode 24, all of which are in parallel with an oscillator. The value of the capacitance between the disc 14 and the post 3 is inversely proportional to the distance t .

It can be shown that if the disc 14 were rigidly attached to the base of the tuning screw 4, the variation of the capacitance with temperature would be a function of the initial value of the distance t and of the coefficient of linear expansion of the cavity material.

That is to say:

$$\Delta C/C_o = -(\alpha_1 \Delta T)/(1 + \alpha_1 \Delta T)$$

(1)

where C_o is the capacitance at some temperature T_o at which temperature the distance t is taken as t_o .

ΔC is the change in capacitance due to a change in temperature ΔT .

α_1 is the coefficient of linear expansion of the cavity material.

It can also be shown that the change Δf of the resonant frequency f_o due solely to the change in capacitance is given by

$$(f_o + \Delta f)^2 = f_o/[1 + (\Delta C/C_o)]$$

(2)

Assuming that $(\Delta f/f_o)^2$ is negligible, which in many typical applications will be a reasonable approximation, an approximate expression for the variation in frequency due to the change in capacitance is

$$\Delta f/\Delta T = \frac{1}{2} \alpha_1 f_o$$

(3)

Hence for a cavity resonator made entirely of brass with an initial resonant frequency f_o of 8GHz, the value of $\Delta f/\Delta T$ will be approximately 80 KHz/°C. (Since α_1 for brass is 2×10^{-5}). The value of $\Delta f/\Delta T$ is dependent on the geometry of the cavity and the operating frequency.

In embodiments of the invention as herein described and illustrated the temperature coefficient adjusting screw 8 forms an attachment between the screw 4 and the stem 12, by the engagement of screw threads 11 and 13 on members 8 and 12 and of screw threads 7 and 9 on members 4 and 8, holding the screw 4 and the

stem 12 in a fixed relationship to one another at a position L_o above the post 3 and furthermore, the distance L_o is adjustable while the gap t_o at temperature T_o between the disc 14 and the post 3 may be set at a predetermined size.

For convenience it is assumed that the tuning screw 4, the adjusting screw 8 and the cavity block 2 and post 3 are all made of brass. The stem 12 and the disc 14 are made of the 36 percent nickel, 64 percent iron alloy known as "INVAR" (Registered Trade Mark). The coefficient of linear expansion α_2 of "INVAR" is taken to be 1×10^{-6} .

The top of the post 3 may be taken as a reference point because everything below it expands at the same rate. The distance L_o between the top of the post 3 and the base of the adjustment screw expands with temperature at a rate given by

$$\Delta L/\Delta T = \alpha_1 L_o$$

where ΔL is the change in L_o due to a change ΔT in temperature.

Similarly, the rate at which the part of the plunger 12, 14 below the adjustment screw 8 expands is given by

$$\Delta X/\Delta T = \alpha_2 X_o$$

where X_o is the length of the plunger below the adjustment screw at a temperature T_o and ΔX is the change in X_o due to a change in temperature ΔT . Clearly $L_o = X_o + t_o$.

The resulting change Δt in the distance t_o between the lower face of the disc 14 and the top face of the post 3 is given by:

$$\Delta t = (L_o \alpha_1 - X_o \alpha_2) \Delta T$$

or

$$\Delta t/t_o = (L_o \alpha_1 - X_o \alpha_2)/t_o \Delta T,$$

so that the term $(L_o \alpha_1 - X_o \alpha_2)/t_o$ can be considered to be the effective coefficient of expansion of the telescopic arrangement, and it will hereinafter be written α_e . Corresponding to equation (3), for the composite telescopic arrangement, the variation of frequency due to the capacitance variation caused by the temperature change ΔT will now be given by

$$\begin{aligned} \Delta f/\Delta T &= \frac{1}{2} \alpha_e f_o = (L_o \alpha_1 - X_o \alpha_2)/2 t_o f_o \\ &= [\frac{1}{2} \alpha_1 + X/2 t_o + (\alpha_1 + \alpha_2)] f_o \end{aligned}$$

If $f_o = 8\text{GHz}$, $L_o = 0.5''$ and $t_o = 0.02''$ then $\Delta f = 1.8\text{MHz/°C}$.

Furthermore, the value of the frequency/temperature coefficient $\Delta f/\Delta T$ can be adjusted by varying the length X_o by turning the screw 8. For instance it may be adjusted to compensate for the temperature dependence of a chosen Gunn oscillator diode.

It will be apparent to those skilled in the art that the invention may be used in connection with waveguide filters and the like.

What I claim is:

1. A coaxial cavity resonator incorporating a telescopic inner conductor which comprises,
 - a tubular tuning screw having an external thread engaged with the structure of one end of the resonator, and having an internally threaded bore,
 - a temperature-coefficient adjusting screw having external and internal threads of substantially the same pitch, the external thread being engaged and

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cooperating with the internal thread of the bore of the said tubular tuning screw,

a stem having an external thread engaged and cooperating with the internal thread on the said temperature coefficient adjusting screw, said stem being formed of a material having a coefficient of thermal expansion different from the coefficient of thermal expansion of the material of the said tuning screw,

a plunger mounted on said stem so as to form a tuning capacitance with the structure of the resonator which capacitance can be varied by adjusting the said tuning screw,

and means for preventing relative rotation of the said stem with respect to the said tuning screw.

2. A coaxial cavity resonator incorporating a telescopic inner conductor as claimed in claim 1, and further including a cylindrical post axially aligned with the

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said inner conductor and having one end thereof attached to the structure of the said resonator, the other end of said cylindrical post forming the main capacitive component of the said resonator in conjunction with said plunger of the said inner conductor.

3. A coaxial cavity resonator as claimed in claim 2 wherein the said telescopic inner conductor also comprises a contacting means located and making electrical contact between the said plunger and the said tuning screw.

4. A coaxial cavity resonator as claimed in claim 3 wherein the contacting means comprises two sets of resilient fingers formed on a single metallic member and mounted so that one of the sets makes electrical contacts with the plunger while the other set makes electrical contacts with the tuning screw.

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