(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 814 364 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.08.2007 Bulletin 2007/31

(51) Int Cl.:
H05B 6/72 (2006.01)

(21) Application number: 07290106.9

(22) Date of filing: 26.01.2007

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: 30.01.2006 JP 2006020215

(71) Applicant: Toshiba Hokuto Electronics Corporation
Asahikawa-shi,
Hokkaido 078-8335 (JP)

(72) Inventors:
- Higashi, M.,
c/o Toshiba Hokuto Electronics Corp.
078-8335 Hokkaido (JP)
- Kawaguchi, Toshio,
Toshiba Corp., IP Division
Minato-ku (JP)

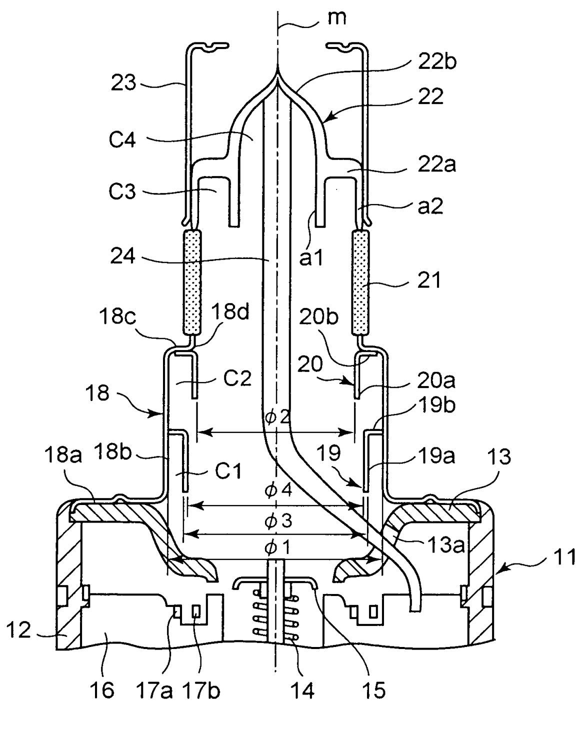
(74) Representative: Uchida, Kenji et al
S.A. Fedit-Loriot et Autres
Conseils en Propriété Industrielle
38, avenue Hoche
75008 Paris (FR)

(54) Magnetron

(57) **Problems:** To provide a magnetron having a λ/4 type choke structure suppressing higher harmonic wave components propagated in a higher order mode or suppressing an unnecessary radiation of the medium band interposed between two higher harmonic waves having frequencies of integer multiples of the fundamental wave.

Means for solving the problems: In a magnetron comprising a high frequency wave generating part 11 generating a high frequency wave, an antenna 24 extracting the high frequency wave, a cylindrical metallic envelope 18 surrounding the antenna 24 and a λ/4 type choke structure C2 suppressing a higher harmonic wave component propagated in a fundamental mode in the metallic envelope 18, another λ/4 type choke structure C1 suppressing a higher harmonic wave component propagated in a higher order mode in the metallic envelope has been provided.

FIG. 1



EP 1 814 364 A2

Description

[0001] The present invention relates to a magnetron used for such as microwave heating devices.

[0002] A magnetron that outputs a high frequency wave, e.g. a magnetron for microwave oven used for cooking or defrosting of foods is constituted of a high frequency wave generating part generating a high frequency wave, an antenna extracting the high frequency wave outside, a cylindrical metallic envelope, which is a part of a vacuum envelope, surrounding the antenna, etc.

[0003] The magnetron for microwave oven generates a microwave with a frequency band of e.g. 2450 MHz. At this time, higher harmonic wave components are generated simultaneously with the fundamental wave component. When the higher harmonic wave components are emitted outside, the higher harmonic wave components are propagated into a heating space of such as a microwave oven together with the fundamental wave component. Because the higher harmonic wave components have short wavelengths and are difficult to be shielded, they leak outside and may cause radio interference. Therefore, a limited value of leakage is stipulated by law.

[0004] Conventional magnetrons for microwave oven are provided with a λ/4 type choke structure in, for example, the output part thereof in order to suppress generation of the higher harmonic wave components (Refer to the Patent Documents 1 to 3). The λ/4 type choke structure is provided with a so-called choke groove whose one end is for example short-circuited and the other end is opened.

[0005] A conventional magnetron will be explained with taking a magnetron for microwave oven as an example, referring to the cross sectional view of FIG. 2 showing a part thereof.

[0006] A high frequency generating part 31, which generates a high frequency wave, is constituted of an anode cylinder 32, etc. Funnel-shaped pole pieces 33 are secured to the top and bottom opening portions of the anode cylinder 32 respectively. Only the pole piece 33 at the top of the figure is shown in FIG. 2 because of the drawing. A spiral cathode 34 is located on the center of the anode cylinder 32 e.g. the tube axis m. Both ends of the cathode 34 are fixed to end-hats 35 respectively. Only the end-hat 35, which fixes the upper end of the cathode 34, is shown in FIG. 2 because of the drawing.

[0007] A plurality of vanes 36 are provided radially toward the cathode 34 from the anode cylinder 32. The vanes 36 are arranged at a certain interval to each other in the direction of the circumference of the anode cylinder 32. One end of the vane 36 is joined to the inner surface of the anode cylinder 32. The other end thereof extends up to the vicinity of the cathode 34 and is a free end. The top side portion and the bottom side portion of each vane 36 are connected with every other one through a pair of large and small strap rings 37a, 37b having diameters different from each other. Only the strap rings 37a, 37b, which connect the top side portions of the vanes 36 together, are shown in FIG. 2 because of the drawing.

[0008] A cylindrical metallic envelope 38 is secured to the output side of the pole piece 33. The lower end of the metallic envelope 38, e.g. the tip of a first annular collar portion 38a expanding outside is joined to the upper end of the anode cylinder 32.

[0009] The metallic envelope 38 is provided therein with a first cylindrical member 39. The first cylindrical member 39 and the metallic envelope 38 form together an annular choke groove, and constitute, for example, a first λ/4 type choke structure C1 suppressing the fifth order higher harmonic wave component.

[0010] A cylindrical ceramic 40 is joined to the upper end 38b of the metallic envelope 38, and an exhaust tube 41 is joined to the upper end of the cylindrical ceramic 40. The exhaust tube 41 is covered entirely with a cap 42.

[0011] The exhaust tube 41 is constituted of e.g. a double cylinder portion 41a, a sealed portion 41b, etc. The double cylinder portion 41a constitutes e.g. a second λ/4 type choke structure C2 suppressing the fourth order higher harmonic wave component. The sealed portion 41b constitutes e.g. a third λ/4 type choke structure C3 suppressing the third order higher harmonic wave component.

[0012] An antenna 43 extracting a high frequency wave generated in a high frequency wave generating portion 31 is provided inside the metallic envelope 38, the cylindrical ceramic 40 and the exhaust tube 41. One end of the antenna 43 is connected to one of the vanes 36. The other end thereof is pinched by and fixed to the exhaust tube 41 after it passes through an opening 33a of the pole piece 33 and extends inside the metallic envelope 38.

[0013] In the structure mentioned above, a high frequency wave generated in the high frequency generating portion 31 is extracted outside through the antenna 43. At this time, higher harmonic wave components simultaneously generated together with the fundamental wave component, e.g. the third order higher harmonic wave component (7.35 GHz) to the fifth order higher harmonic wave component (12.25 GHz) are suppressed by the first to the third λ/4 type choke structures C1 to C3.

The prior art includes the following patent documents:

Patent Document 1: Japanese Patent Publication No. 961611; Patent Document 2: Japanese Patent Publication No. 2128827; and Patent Document 3: Japanese Patent Laid-Open No.Sho63-264848.

In view of the above prior art, the present invention relates to a magnetron comprising;

a high frequency wave generating part generating a high frequency wave,

an antenna extracting the high frequency wave,
a cylindrical metallic envelope surrounding the antenna, and
a plurality of λ/4 type choke structures comprising a choke groove having a length in the axial direction of the magnetron and being mounted in the metallic envelope,
characterized in that the plurality of λ/4 type choke structures comprise at least a first λ/4 type choke structure suppressing a first higher harmonic wave component in a fundamental mode that propagates inside the metallic envelope, and at least a second λ/4 type choke structure suppressing a second higher harmonic wave component in a higher order mode, compared to the fundamental mode, that propagates inside the metallic envelope.
Preferably, the at least a first λ/4 type choke structure and the at least a second λ/4 type choke structure are placed in a same single choke groove, so that said single choke groove can suppress both said first higher harmonic wave component in a fundamental mode and said second higher harmonic wave component in a higher order mode..
Thus, this one single choke groove can perform two functions, namely the function for suppressing the first higher harmonic wave component in a fundamental mode and the function for suppressing the second higher harmonic wave component in a higher order mode compared to the fundamental mode.
The invention also concerns a magnetron comprising;
a high frequency wave generating part generating a high frequency wave,
an antenna extracting the high frequency wave,
a cylindrical metallic envelope surrounding the antenna, and
a cylindrical member forming a choke groove of a λ/4 type choke structure in the metallic envelope,
characterized in that the choke groove is set to have a length suppressing both a first higher harmonic wave component being propagated inside the metallic envelope in a fundamental mode and a second higher harmonic wave component having a frequency different from the first higher harmonic wave component being propagated inside the metallic envelope in a higher order mode.
Preferably, relationship is represented by

$$\lambda_c = \pi(a+b)$$

and

$$\lambda_g = \lambda_n \Big/ \sqrt{1 - \left(\frac{\lambda_n}{\lambda_c}\right)^2}$$

where the higher order mode is TE11 mode, the guide wavelength of the first higher harmonic wave component propagated in the fundamental mode being λ_g, the wavelength in the free space of the second higher harmonic wave component being λ_n, the cutoff wavelength of TE11 mode propagated inside the metallic envelope being λ_c, the radius of the outer peripheral surface of the cylindrical member of the choke groove being a, the radius of the inner peripheral surface of the metallic envelope of the choke groove being b, and the length of the choke groove being $\lambda_g/4$.
Typically, the frequency of the first higher harmonic wave component is between two higher harmonic wave components having frequencies adjacent to each other by integer multiples of the fundamental wave.
The frequency of the first higher harmonic wave component may be located approximately at a central position of two higher harmonic wave components having frequencies adjacent to each other by integer multiples of the fundamental wave.
The invention further relates to a magnetron comprising;

a high frequency wave generating part generating a high frequency wave,
an antenna extracting the high frequency wave,
a cylindrical metallic envelope surrounding the antenna, and
a cylindrical member forming a choke groove of a λ/4 type choke structure in the metallic envelope,

characterized in that the choke groove is set to have a size suppressing both an N/2th order higher harmonic wave component (N≧3) being propagated inside the metallic envelope in a fundamental mode and an (N+1)/2th higher harmonic wave component (N≧3) being propagated inside the metallic envelope in TE 11 mode.
Preferably, relationship is represented by

$$\lambda_c=\pi(a+b)$$

and

$$\lambda_g = \lambda_n \Big/ \sqrt{1-\left(\frac{\lambda_n}{\lambda_c}\right)^2}$$

where the guide wavelength of the (N/2)th order higher harmonic wave component (N≧3) propagated in the fundamental mode is λ_g, the wavelength in the free space of the ((N+1)/2)th order higher harmonic wave component (N≧3) being λ_n, the cutoff wavelength of TE11 mode propagated inside the metallic envelope being λ_c, the radius of the outer peripheral surface of the cylindrical member of the choke groove being a, the radius of the inner peripheral surface of the metallic envelope of the choke groove being b, and the length of the choke groove being $\lambda_g/4$.

The above, and the other objects, features and advantages of the present invention will be made apparent from the following description of the preferred embodiments, given as non-limiting examples, with references to the accompanying drawings, in which:

FIG. 1 is a schematic cross sectional view explaining an embodiment of the present invention; and
FIG. 2 is a schematic cross sectional view explaining a conventional example;

Wherein 11: high frequency wave generating part, 12: anode cylinder, 13: pole piece, 14: cathode, 15: end hat, 16: vane, 17a, 17b: strap ring, 18: metallic envelope, 19: first cylindrical member, 20: second cylindrical member, 21: cylindrical ceramic, 22: exhaust tube, 23: cap, 24: antenna

C1 to C4: first to fourth λ/4 type choke structures, m: tube axis.

[0014] Conventional magnetrons such as a magnetron for microwave oven suppress higher harmonic wave components by providing a plurality of λ/4 type choke structures in the output part thereof. The λ/4 type choke structure has a coaxial double cylinder structure comprised of e.g. an inner cylinder and an outer cylinder, and a so-called choke groove, which is short-circuited at one end thereof and opened at the other end thereof, is formed for example between the inner cylinder and the outer cylinder. The length of the choke groove, e.g. the size of the choke groove in the direction of the tube axis is usually set to be approximately a quarter of higher harmonic wave components to be suppressed.

[0015] In the λ/4 type choke structure, the electric field is concentrated on the open end of the choke groove and a capacitance component is generated. Therefore, it has been known that influence of the stray capacitance becomes large as the frequency becomes high, so that higher harmonic wave suppressing effect can be obtained by a size shorter than the theoretical quarter wavelength.

[0016] Experience has also shown that higher harmonic wave suppressing effect becomes large when the inner length of the choke groove, i.e. the length measured along the inner surface thereof from one open end of the choke groove to the other open end opposite thereto (the creepage distance of the choke groove) becomes a length close to the half wavelength of the relevant higher harmonic wave component.

[0017] For example, a quarter wavelength of the fifth higher harmonic wave component (12.25 GHz) is approximately 6.12 mm. However, the length of the actual choke groove is approximately 5 mm, e.g. 4 to 6 mm according to the empirical rule relevant to influence of the stray capacitance or the inner length of the choke groove.

[0018] As the inner diameter of the λ/4 type choke structure becomes small, the distance to the antenna becomes short, so that the higher harmonic wave suppressing effect becomes large. However, productivity is deteriorated if the inner diameter is small. Besides, multipactor discharge likely takes place, for example, between the antenna and the cylindrical member of the choke structure parts. Furthermore, there is a problem that the region of unstable oscillation becomes wider because the impedance, the power source and the load condition, etc. of such as a heating device like a microwave oven are large due to coupling with the antenna coming to be strengthened.

[0019] It is assumed that propagation is carried out in the fundamental mode of the coaxial line constituted of the antenna as an inner conducting member and the metallic envelope as an outer conducting member, so-called TEM mode for the λ/4 type choke structure used for conventional magnetrons for microwave oven. The dimensions of the choke groove are also based on a quarter of the wavelength in the free space. However, propagation in a higher order mode of higher harmonic wave components is possible contingent upon sizes of the diameters of the inner conducting member and the outer conducting member acting as the coaxial line.

[0020] For example, the radius of the circle formed by the outer peripheral surface of the inner conducting member

(1/2 of the outer diameter of the inner conducting member) is a when the inner conducting member constituting the coaxial line is cut off; the radius of the circle formed by the inner peripheral surface of the outer conducting member (1/2 of the inner diameter of the outer conducting member) is b when the outer conducting member is cut off; and the cutoff wavelength of TEn1 mode is λ_c. Then, the relationship among them is represented by formula (1).

[0021]

$$\lambda_c=\pi(a+b)/n \qquad (1)$$

According to the formula (1), propagation in a higher order mode is possible if the value of $\pi(a+b)$ is larger than λ_c in the case of TE11 mode. For instance, the fifth order higher harmonic wave component can be propagated in a higher order mode (TE11 mode) if the inner diameter of the outer conducting member is 13.08 mm or more in the case of the outer diameter of the inner conducting member being 2.5 mm. Therefore, propagation in TE11 mode comes to be possible when the inner diameter of the λ/4 type choke structure is increased in order to prevent deterioration of productivity or to stabilize the oscillation.

[0022] If propagation in a higher order mode, e.g. TE11 mode comes to be possible, the relevant higher harmonic wave selects primarily the lower one, which is easier to be propagated than another, out of the load impedance of TEM mode and the load impedance of TE11 mode.

[0023] In a conventional λ/4 type choke structure, the size of the choke groove is determined based on a quarter of the wavelength in the free space. Besides, even for the same higher harmonic wave component, the guide wavelengths for the fundamental mode and a higher order mode are different from each other. In consequence, though the λ/4 type choke structure used for a conventional magnetron for microwave oven can suppress the higher harmonic wave component propagated in the fundamental mode, it cannot sufficiently suppress the higher order mode because of the wavelength being different, so that the relevant higher harmonic wave component leaks.

[0024] Moreover, dimensions etc. are set in a conventional λ/4 type choke structure so as to suppress the Nth order higher harmonic wave component (hereafter called 'ordinary higher harmonic wave component') having integer multiples of the fundamental wave. In fact, higher harmonic wave components in a band interposed between two ordinary higher harmonic wave components adjacent to each other such as a band interposed between the frequency of the third order higher harmonic wave component and the frequency of the fourth order higher harmonic wave component (hereafter called 'higher harmonic wave component of the medium band') are also generated. In some cases, unnecessary radiation components such as the 3.5th order higher harmonic wave component or the 4.5th order higher harmonic wave component located nearly at the center of the medium band may reach a high level equal to or higher than the ordinary higher harmonic wave component.

[0025] Conventional λ/4 type choke structures have a problem that the higher harmonic wave component of the medium band cannot be suppressed so sufficiently that it leaks. Besides, there are problems that the cost rises or the device becomes large-scaled if a λ/4 type choke structure for the medium band is provided additionally in order to suppress the higher harmonic wave components of the medium band.

[0026] The present invention is intended to provide a magnetron having a λ/4 type choke structure that suppresses a higher harmonic wave component propagated in a higher order mode or suppresses a higher harmonic wave component of the medium band upon overcoming the drawbacks mentioned above.

[0027] An aspect of the present invention is a magnetron comprising; a high frequency wave generating part generating a high frequency wave, an antenna extracting the high frequency wave, a cylindrical metallic envelope surrounding the antenna, and a first λ/4 type choke structure suppressing a higher harmonic wave component being propagated inside the metallic envelope in a fundamental mode, wherein the magnetron is provided with a second λ/4 type choke structure suppressing the higher harmonic wave component being propagated inside the metallic envelope in a higher order mode.

[0028] Another aspect of the present invention is a magnetron comprising; a high frequency wave generating part generating a high frequency wave, an antenna extracting the high frequency wave, a cylindrical metallic envelope surrounding the antenna, and a cylindrical member forming a choke groove having a λ/4 type choke structure in the metallic envelope, wherein the choke groove is set to have a length suppressing both a first higher harmonic wave component being propagated inside the metallic envelope in a fundamental mode and a second higher harmonic wave component having a frequency different from the first higher harmonic wave component being propagated inside the metallic envelope in a higher order mode.

[0029] According to the present invention, a λ/4 type choke structure suppressing higher harmonic wave components propagated in the fundamental mode is provided and a λ/4 type choke structure suppressing the same higher harmonic wave components propagated in a higher order mode is also provided. In consequence, one higher harmonic wave component can be surely suppressed even if it can be propagated in both the fundamental mode and a higher order mode, so that the higher harmonic wave component is prevented from leaking.

[0030] Furthermore, one λ/4 type choke structure can suppress simultaneously a first higher harmonic wave component propagated in the fundamental mode and a second higher harmonic wave component having a frequency different therefrom propagated in a higher order mode. As a result, a plurality of higher harmonic wave components having propagation modes different from one another can be suppressed by a common λ/4 type choke structure, so that higher harmonic wave components can be prevented from leaking without raising the cost.

[0031] Some embodiments of the present invention will be explained referring to the cross sectional view shown by FIG. 1, taking a magnetron for microwave oven as an example.

[0032] A high frequency wave generating part 11 generating a high frequency wave is comprised of an anode cylinder 12, etc. Funnel-shaped pole pieces 13 are fixed to the opened portions of the anode cylinder 12, e.g. the opened portions of both the output side at the top of the figure and the input side at the bottom of the figure respectively. Only the pole piece 13 of the output side is shown in FIG. 1 because of the drawing. A spiral cathode 14 is located on the center of the anode cylinder 12, e.g. the tube axis m.

[0033] Both ends of the cathode 14 at the top and the bottom of the figure are fixed to end-hats 15 respectively. Only the end-hat 15, which fixes the upper end of the cathode 14 e.g. the output side, is shown in FIG. 1 because of the drawing.

[0034] A plurality of vanes 16 are provided radially toward the cathode 14 from the anode cylinder 12. The vanes 16 are, for example, rectangular and arranged at a certain interval to each other in the direction of the circumference of the anode cylinder 12. One end of the vane 16 is joined to the inner surface of the anode cylinder 12. The other end thereof extends up to the vicinity of the cathode 14 and is a free end. A pair of large and small strap rings 17a, 17b having diameters different from each other are positioned along the top side portion and the bottom side portion of vanes 16. Each vane 16 is connected with every other one through the strap ring 17a or the strap ring 17b. Only the strap rings 17a and 17b, which connect the top sides of the vanes 16 together, are shown in FIG. 1 because of the drawing.

[0035] A cylindrical metallic envelope 18 is secured to the output side of the pole piece 13. The metallic envelope 18 is comprised of, for example, an annular first collar part 18a positioned at the lower end of the figure and expanding outward, a cylindrical part 18b elongated in parallel with the tube axis m, an annular second collar part 18c extending inward from the upper end of the cylindrical part 18b, a crooked part 18d bended in the direction of the tube axis m from the second collar part 18c, etc. The end edge of the first collar part 18a is joined to the upper end of the anode cylinder 12.

[0036] A first cylindrical member 19 is joined to the inner side of the metallic envelope 18, e.g. the inner side of the cylindrical part 18b. The first cylindrical member 19 has, for example, a cylindrical part 19a extended in parallel with the tube axis m, an annular collar part 19b extended outward perpendicularly to the tube axis m from the upper end of the cylindrical part 19a, etc., and the cross section thereof has an inverted L-shape. The cylindrical part 19a is located coaxially with the cylindrical part 18b of the metallic envelope 18, and the annular edge surface of the collar part 19b is joined to the inner surface of the metallic envelope 18.

[0037] The metallic envelope 18 and the first cylindrical member 19 configure an annular choke groove in which the upper ends thereof in the figure are short-circuited together and the lower ends thereof in the figure are opened, constituting a first λ/4 type choke structure C1. The length of the choke groove forming the first λ/4 type choke structure C1 is measured in the direction of the tube axis m, e.g. the length of the metallic envelope 18 facing the cylindrical part 19a of the first cylindrical member 19. In other words, the length of the groove is measured in the axial direction of the magnetron, i.e. in the direction of the depth of the groove. This length is set to be a size suppressing both the 4.5th order higher harmonic wave component having a frequency of 4.5 times of the fundamental wave and propagated in the fundamental mode, and the fifth order higher harmonic wave component having a frequency of 5 times of the fundamental wave and propagated in a higher order mode as mentioned after.

[0038] An annular second cylindrical member 20 is joined to the inner side of the metallic envelope 18, e.g. the bottom surface of the second collar part 18c in the drawing. The second cylindrical member 20 is constituted of a cylindrical part 20a, a collar part 20b, etc. The second cylindrical member 20 has a shape similar to the first cylindrical member 19 though their dimensions are different from each other, and the cross section thereof has nearly an inversed L-shape.

[0039] The metallic envelope 18 and the second cylindrical member 20 form together an annular choke groove as is the case with the first λ/4 type choke structure C1, and compose a second λ/4 type choke structure C2 suppressing e.g. the fifth order higher harmonic wave component having a frequency of 5 times of the fundamental wave and propagated in the fundamental mode.

[0040] A cylindrical ceramic 21 is joined to the upper end of the metallic envelope 18, e.g. the edge of the crooked part 18d. The exhaust tube 22 is joined to the upper end of the cylindrical ceramic 21, and the exhaust tube 22 is entirely covered with a cap 23.

[0041] The exhaust tube 22 is constituted of, for example, a double cylinder part 22a, a sealed part 22b, etc. The double cylinder part 22a is constituted of, for example, an inner cylinder part a1, an outer cylinder part a2, etc. An annular choke groove is formed between the inner cylinder part a1 and the outer cylinder part a2, and composes, for example, a third λ/4 type choke structure C3 which suppresses the fourth order higher harmonic wave component having a frequency of 4 times of the fundamental wave. The inner cylinder part a1 and the sealed part 22b form a continuing space inside them.

[0042] For example, the sealed part 22b protrudes upward at the center thereof. The inside space of the sealed part 22b and the inner cylinder part a1 composes a fourth λ/4 type choke structure C4 which suppresses the third order higher harmonic wave component having a frequency of 3 times of the fundamental wave.

[0043] Inside the metallic envelope 18, the cylindrical ceramic 21, the exhaust tube 22, etc., an antenna 24 that extracts a high frequency wave generated by the high frequency wave generating part 11 is provided. One end of the antenna 24 is connected to one of the vanes 16, and the other end thereof is pinched by and fixed to the sealed part 22b of the exhaust tube 22 after it passes through an opening 13a of the pole piece 13 and extends inside the metallic envelope 18.

[0044] The first and the second λ/4 type choke structures C1 and C2 mentioned above will be explained here. In the following explanation, the inner diameterφ1 of the cylindrical part 18b of the metallic envelope 18 is 19 mm; the outer diameter of the antenna 24 is 2.5 mm; the inner diameterφ2 of the cylindrical part 20a of the second cylindrical member 20 is 14 mm; and the thickness of the cylindrical part 20a is 0.3 mm.

[0045] As to the first λ/4 type choke structure C1, the size of the choke groove in the direction of the tube axis m is configured so as to suppress TEM mode of the 4.5th higher harmonic wave and TE11 mode of the fifth higher harmonic wave. For instance, the outer diameter φ3 of the cylindrical part 19a of the first cylindrical member 19 is determined in order that the length of the portion where the cylindrical part 18b of the metallic envelope 18 and the cylindrical part 19a of the first cylindrical member 19 face together in parallel can be equal to a quarter of the guide wavelengths of both the TEM mode of the 4.5th order higher harmonic wave and the TE11 mode of the fifth order higher harmonic wave.

[0046] In general, the guide wavelength (λ_g) can be found by the following formula (2):

$$\lambda_g = \lambda_n \Big/ \sqrt{1 - \left(\frac{\lambda_n}{\lambda_c}\right)^2} \qquad (2)$$

[0047] If the 4.5th order higher harmonic wave is 11 GHz, the guide wavelength of TEM mode is 27.254 mm. Upon using the formula (1) and the formula (2), the outer diameter φ3 of the cylindrical part 19a of the first cylindrical member 19 is found in order that the guide wavelength of TE11 mode of the fifth order higher harmonic wave is 27.254 mm.

[0048] When λ_g=27.254 mm and λ_n (the wavelength in the free space of the fifth order higher harmonic wave)=24.473 mm are substituted in the formula (2), λ_c=55.61 mm is found.

[0049] When λ_c=55.61 mm is substituted in the formula (1) next, it becomes 55.61=π(a+b). As b=19/2=9.5, it is found that a=8.2.

[0050] Here, a is the radius of the outer peripheral surface of the cylindrical member 19 of the choke groove part, that is to say, the radius of the circle formed by the outer peripheral surface of the cylindrical part 19a when the cylindrical part 19a parallel to the tube axis m of the first cylindrical member 19 is cut off, and b is the radius of the inner peripheral surface of the cylindrical part 18b of the choke groove part, that is to say, the radius of the circle formed by the inner peripheral surface of the cylindrical part 18b when the cylindrical part 18b parallel to the tube axis m of the metallic envelope 18 is cut off.

[0051] Therefore, when the outer diameter φ3 of the cylindrical part 19a of the first cylindrical member 19 is 16.4 mm (8.2×2) and the thickness of the plate is 0.3 mm, then the inner diameter φ4 is 15.8 mm.

[0052] If the diameters of the cylindrical part 18b of the metallic envelope 18 and the cylindrical part 19a of the first cylindrical member 19 are set to be the dimensions mentioned above, the guide wavelength of TEM mode of the 4.5th order higher harmonic wave comes to be equal to the guide wavelength of TE11 mode of the fifth order higher harmonic wave. Consequently, TEM mode of the 4.5th order higher harmonic wave and TE11 mode of the fifth order higher harmonic wave can be suppressed by the first λ/4 type choke structure C 1.

[0053] A quarter of the wavelength of the 4.5th order higher harmonic wave is 6.813 mm (27.254/4 mm). However, if the inner length of the choke groove (the creepage distance) is set to be a half wavelength (13.626 mm), the actual length of the choke groove in the direction of the tube axis is approximately 6.2 mm.

[0054] As to the second cylindrical member 20, the length of the cylindrical part 20a of the second cylindrical member 20 in the direction of the tube axis m is set to be a quarter of the guide wavelength of the fundamental mode (TEM mode). The guide wavelength of the fundamental mode is equal to the wavelength in the free space, and a quarter of the wavelength is 6.12 mm. In this case, if the inner length of the choke groove (the creepage distance) is set to be a half wavelength (12.24 mm), the actual length of the choke groove is approximately 5 mm.

[0055] The embodiment mentioned above is explained when the fifth order higher harmonic wave component propagated in the fundamental mode and a higher order mode is suppressed by means of the first and the second λ/4 type choke structures. However, other order higher harmonic wave components propagated in the fundamental mode and a higher order mode can be suppressed if the dimensions of the λ/4 type choke structure are appropriately set.

[0056] The metallic envelope and the cylindrical member are formed separately and then joined together. However, the metallic envelope and the cylindrical member can also be formed integrally.

[0057] According to the structure mentioned above, one higher harmonic wave component can be suppressed when it is propagated not only in the fundamental mode but also in a higher order mode, so that higher harmonic wave components can be prevented from leaking outside. In addition, higher harmonic wave components in the medium band can also be suppressed, so that higher harmonic wave components can be surely prevented from being radiated unnecessarily to the outside.

[0058] The higher harmonic wave components in the medium band usually have the maximum value at the central portion of the medium band (for example, the range from the 4th to the 6th sections counted from the low frequency side when the medium band interposed between two higher harmonic wave components is equally divided into 10 sections). In consequence, prevention effect for leakage to the outside becomes large if the higher harmonic wave components of the central portion in the medium band, e.g. the 3.5th order higher harmonic wave component or the 4.5th order higher harmonic wave component are suppressed.

[0059] Besides, by means of one λ/4 type choke structure, ordinary higher harmonic wave components and higher harmonic wave components in the medium band can be simultaneously suppressed. Therefore, leakage of higher harmonic wave components to the outside can be diminished or prevented without raising the cost.

[0060] There is a limit to the range capable of regulating the guide wavelength by changing the diameter of the cylindrical member, in the case of suppressing simultaneously ordinary higher harmonic wave components and higher harmonic wave components in the medium band. As a result, it is desirable that the frequencies of both the higher harmonic wave components to be suppressed simultaneously are close to each other. Additionally, the guide wavelength of TE11 mode becomes longer than that of the fundamental mode. In consequence, when the ordinary higher harmonic wave component and the higher harmonic wave component in the medium band are simultaneously suppressed, combination thereof is preferably e.g. the (N/2)th order higher harmonic wave component (N≥3) propagated in the fundamental mode and the ((N+1)/2)th higher harmonic wave component (N≥3) propagated in TE11 mode.

[0061] The metallic envelope of too large dimensions is not used so as not to become large-scaled. As a result, possibility of propagation of a higher order mode than TE11 mode is small, so that actual problems do not occur if TE11 mode is suppressed as to a higher order mode.

[0062] According to the structure mentioned above, higher harmonic wave components propagated in a higher order mode, e.g. TE11 mode can be suppressed. Consequently, the inner diameter of the cylindrical member forming the choke groove, etc. can be increased, so that multipactor discharge or instability of oscillation can be prevented.

[0063] In the embodiments mentioned above, expressions such as 'the first' to 'the fourth' are employed. These ordinal numbers do not mean a special content such as the order or the position, but are merely used for distinguishing other one.

[0064] The embodiments above have a structure in which the direction of λ/4 type choke structure, e.g. the direction of the free end of the choke groove thereof faces the input side. However, the free end of the choke groove can face the output side, and the same effects can also be obtained by this structure.

Claims

1. A magnetron comprising;
   a high frequency wave generating part generating a high frequency wave,
   an antenna extracting the high frequency wave,
   a cylindrical metallic envelope surrounding the antenna, and
   a plurality of λ/4 type choke structures comprising a choke groove having a length in the axial direction of the magnetron and being mounted in the metallic envelope,
   characterized in that said plurality of λ/4 type choke structures comprise at least a first λ/4 type choke structure suppressing a first higher harmonic wave component in a fundamental mode that propagates inside the metallic envelope, and at least a second λ/4 type choke structure suppressing a second higher harmonic wave component in a higher order mode, compared to said fundamental mode, that propagates inside the metallic envelope

2. A magnetron as set forth in claim 1, wherein said at least a first λ/4 type choke structure and said at least a second λ/4 type choke structure are placed in a single choke groove, so that said single choke groove can suppress both said first higher harmonic wave component in a fundamental mode and said second higher harmonic wave component in a higher order mode.

3. A magnetron comprising;
   a high frequency wave generating part generating a high frequency wave,
   an antenna extracting the high frequency wave,

a cylindrical metallic envelope surrounding the antenna, and
a cylindrical member forming a choke groove of a λ/4 type choke structure in the metallic envelope,
characterized in that the choke groove is set to have a length suppressing both a first higher harmonic wave component being propagated inside the metallic envelope in a fundamental mode and a second higher harmonic wave component having a frequency different from the first higher harmonic wave component being propagated inside the metallic envelope in a higher order mode.

4. The magnetron as set forth in Claim 3, wherein relationship is represented by

$$\lambda_c=\pi(a+b)$$

and

$$\lambda_g = \lambda_n \Bigg/ \sqrt{1-\left(\frac{\lambda_n}{\lambda_c}\right)^2}$$

where the higher order mode is TE 11 mode, the guide wavelength of the first higher harmonic wave component propagated in the fundamental mode being λ_g, the wavelength in the free space of the second higher harmonic wave component being λ_n, the cutoff wavelength of TE11 mode propagated inside the metallic envelope being λ_c, the radius of the outer peripheral surface of the cylindrical member of the choke groove being a, the radius of the inner peripheral surface of the metallic envelope of the choke groove being b, and the length of the choke groove being $\lambda_g/4$.

5. The magnetron as set forth in Claim 3 or 4, wherein the frequency of the first higher harmonic wave component is between two higher harmonic wave components having frequencies adjacent to each other by integer multiples of the fundamental wave.

6. The magnetron as set forth in Claim 3 or 4, wherein the frequency of the first higher harmonic wave component is located approximately at a central position of two higher harmonic wave components having frequencies adjacent to each other by integer multiples of the fundamental wave.

7. A magnetron comprising;
a high frequency wave generating part generating a high frequency wave,
an antenna extracting the high frequency wave,
a cylindrical metallic envelope surrounding the antenna, and
a cylindrical member forming a choke groove of a λ/4 type choke structure in the metallic envelope,
characterized in that the choke groove is set to have a size suppressing both an N/2th order higher harmonic wave component (N≥3) being propagated inside the metallic envelope in a fundamental mode and an (N+1)/2th higher harmonic wave component (N≥3) being propagated inside the metallic envelope in TE11 mode.

8. The magnetron as set forth in Claim 7, wherein relationship is represented by

$$\lambda_c=\pi(a+b)$$

and

$$\lambda_g = \lambda_n \Bigg/ \sqrt{1-\left(\frac{\lambda_n}{\lambda_c}\right)^2}$$

where the guide wavelength of the (N/2)th order higher harmonic wave component (N≥3) propagated in the fundamental mode is λ_g, the wavelength in the free space of the ((N+1)/2)th order higher harmonic wave component (N≥3) being λ_n, the cutoff wavelength of TE11 mode propagated inside the metallic envelope being λ_c, the radius of the outer peripheral surface of the cylindrical member of the choke groove being a, the radius of the inner peripheral surface of the metallic envelope of the choke groove being b, and the length of the choke groove being $\lambda_g/4$.

FIG. 1

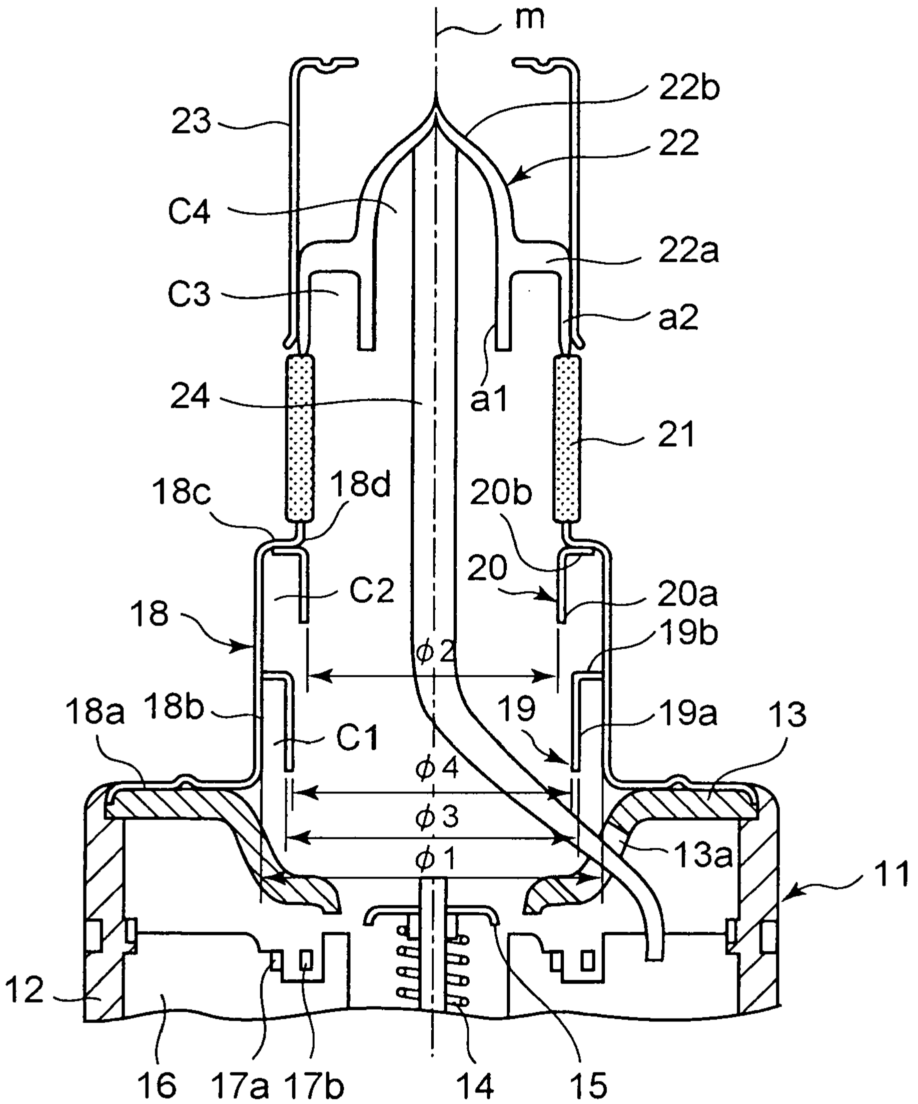
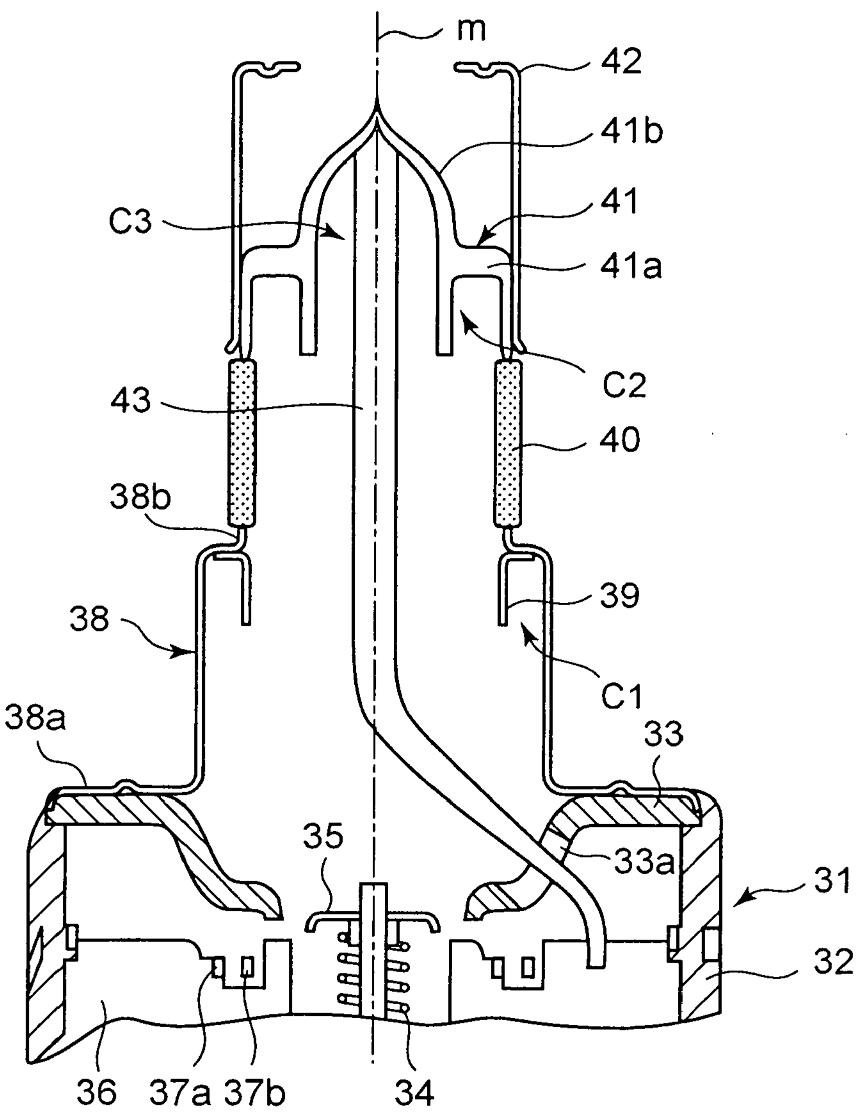

m
23
22b
22
C4
22a
C3
a2
a1
24
21
18c
18d
20b
20
C2
20a
18
19b
$\phi 2$
18a
18b
19
19a
13
C1
$\phi 4$
$\phi 3$
13a
$\phi 1$
11
12
16
17a
17b
14
15

FIG. 2


m
42
41b
41
41a
C3
C2
43
40
38b
39
38
C1
38a
33
35
33a
31
32
36
37a
37b
34

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 961611 A **[0013]**
- JP 2128827 A **[0013]**
- JP 63264848 A **[0013]**