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(54) **MICROWAVE FEEDING SYSTEM**

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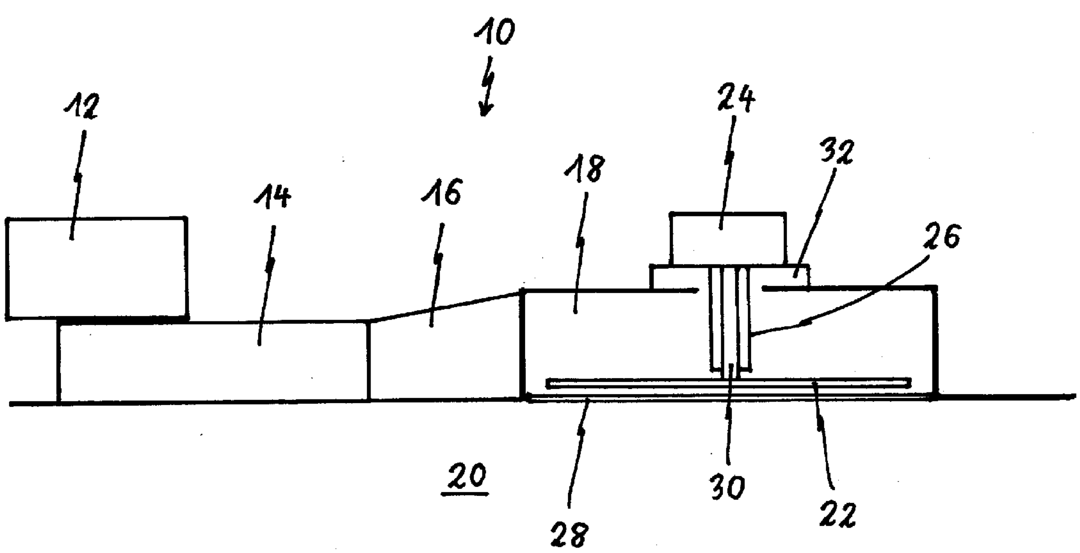
(57) **ABSTRACT**

A microwave feeding system (**10**) for a microwave oven or an oven with microwave heating function, wherein the microwave feeding system (**10**) comprises a magnetron (**12**), a rectangular waveguide (**14**) and a cylindrical cavity (**18**), the cylindrical cavity (**18**) is connected or connectable to an oven cavity (**20**), a rotatable omnidirectional antenna (**22**) is arranged inside the cylindrical cavity (**18**), the omnidirectional antenna (**22**) is driven by an antenna motor (**24**), the omnidirectional antenna (**22**) is connected to the antenna motor (**24**) via a shaft (**30**) made of conductive material, an inner cavity (**26**) is arranged inside the cylindrical cavity (**18**), the inner cavity (**26**) is arranged coaxially to the cylindrical cavity (**18**), the inner cavity (**26**) encloses at least partially the shaft (**30**), and the inner cavity (**26**) and the shaft (**30**) are arranged coaxially to each other, characterised in that the magnetron (**12**), the rectangular waveguide (**14**) and the cylindrical cavity (**18**) are connected in straight series, wherein the microwave feeding system (**10**) provides elliptically polarized TEM electromagnetic waves for the oven cavity (**20**), and wherein the omnidirectional antenna (**22**) acts as a continuous phase shifter, and wherein an inner diameter of the cylindrical cavity (**18**) is between 0.75 and three multiples of the wave-length of the microwaves guided within said cylindrical cavity (**18**).



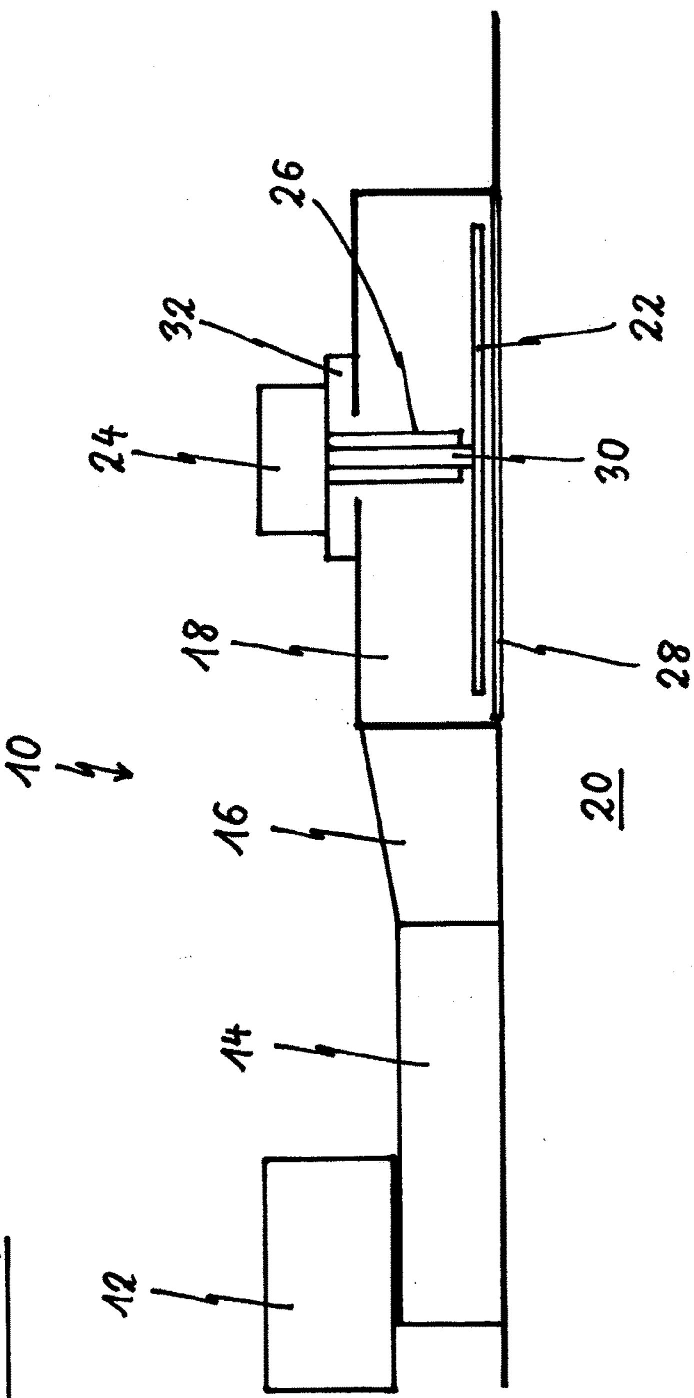


FIG 1

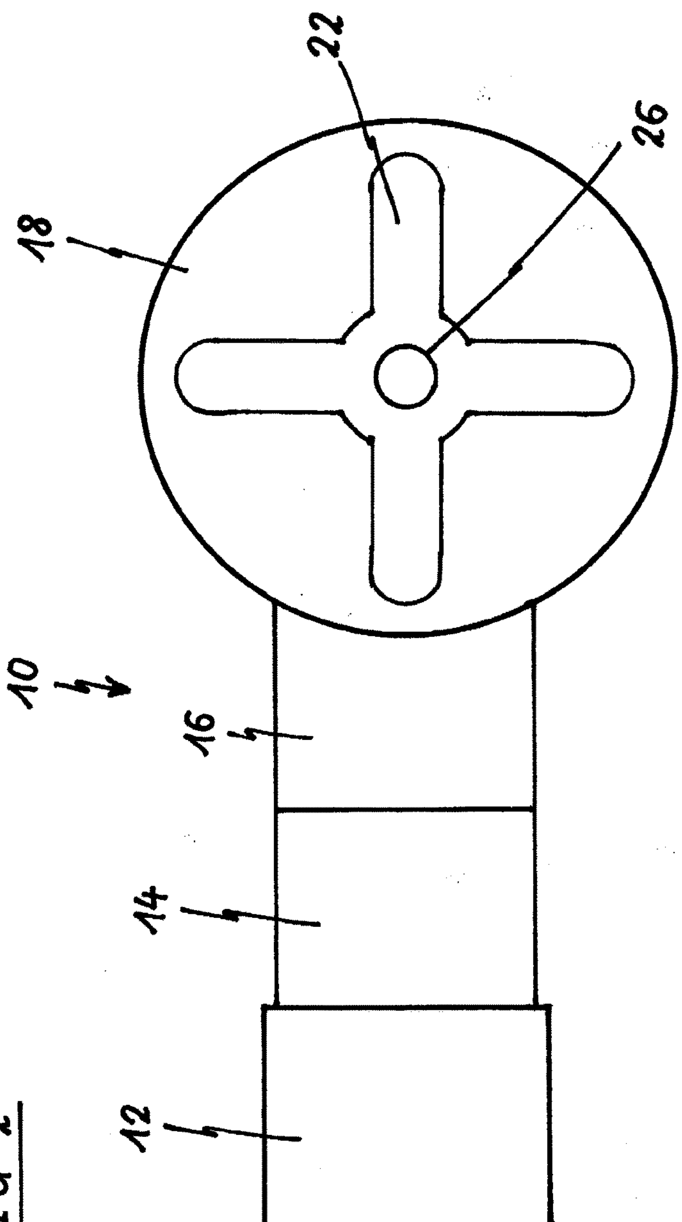


FIG 2

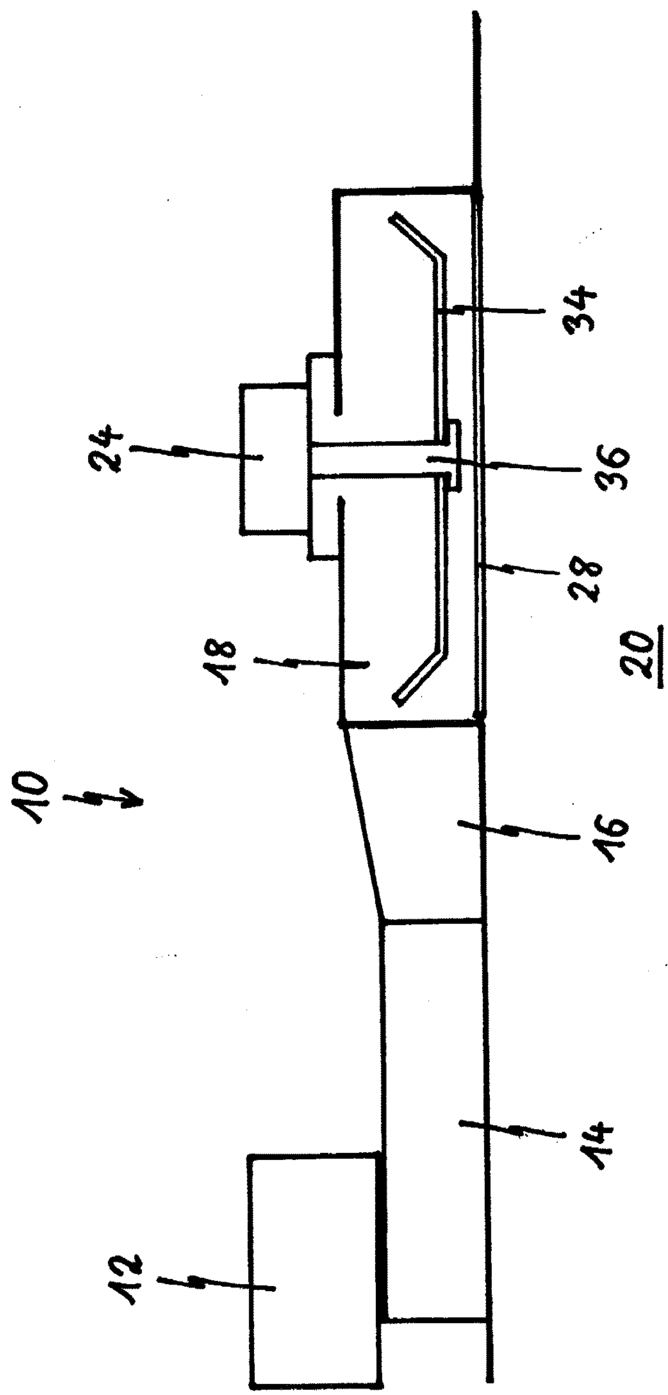


FIG 3

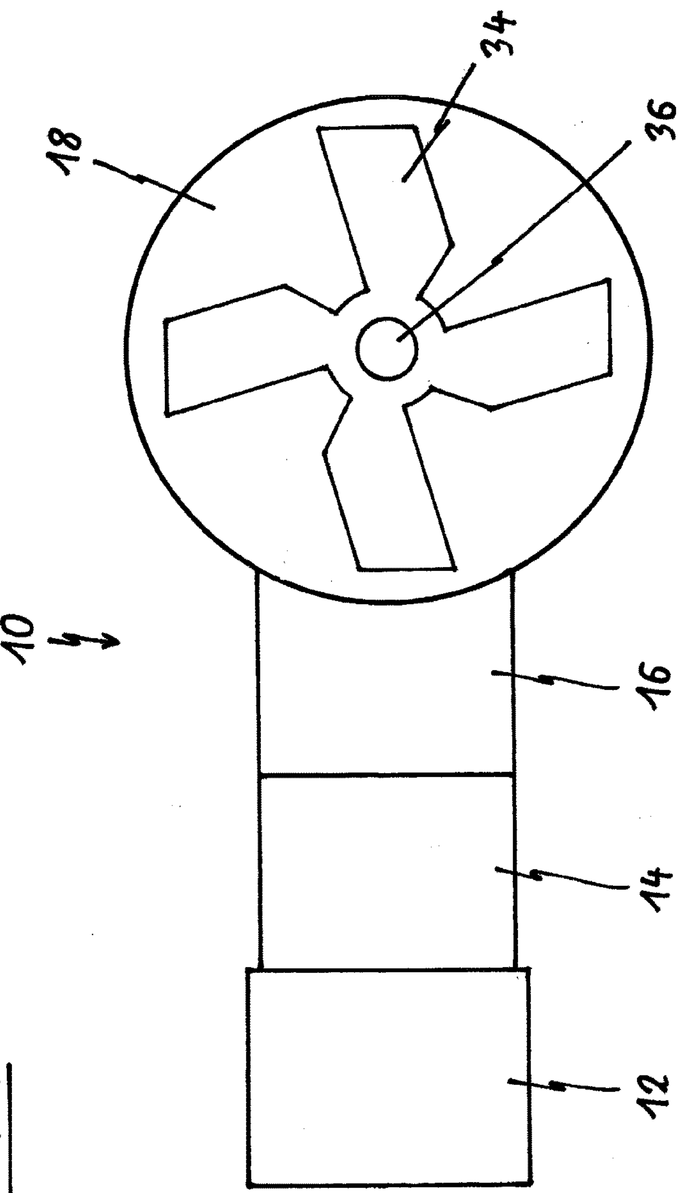


FIG 4

MICROWAVE FEEDING SYSTEM

[0001] The present invention relates to a microwave feeding system for a microwave oven or for an oven with microwave heating function according to the preamble of claim **1**. Further, the present invention relates to a microwave oven or an oven with microwave heating functions.

[0002] Current microwave feeding systems provide a power efficiency of not more than about 55%, since a substantial amount of the power delivered by a magnetron is lost by reflecting phenomenon and by heating of the outside body of said magnetron.

[0003] FIG. **3** illustrates a schematic sectional side view of an example of the microwave feeding system according to the prior art. The microwave feeding system **10** comprises a magnetron **12**, a rectangular waveguide **14**, a Chebyshev waveguide transformer **16** and a cylindrical cavity **18**. A wave stirrer **34** is arranged inside the cylindrical cavity **18**. The wave stirrer **34** is driven by a motor **24** and connected to said motor **24** via a stirrer shaft **36**. Said stirrer shaft **36** is made of dielectric material.

[0004] FIG. **4** illustrates a schematic sectional top view of the microwave feeding system **10** for the microwave oven according to the prior art. The wave stirrer **34** includes four stirrer blades. The wave stirrer **34** shifts the phase of the electromagnetic waves, but this is not sufficient for improving the microwave distribution, since there is a big variation of the impedance between the location point of the antenna of the magnetron **12** and the oven cavity **20**. This results in an efficiency of the power consumption of not more than 50% to 55%. The blades of the wave stirrer **34** reflect a part of the microwave energy back to the antenna of the magnetron **12**, so that an outer body of said magnetron **12** is heated up. The microwave feeding system **10** of the prior art generates only linearly polarized TE and TM electromagnetic waves resulting in a standing wave picture in the oven cavity **20**. The only phase changing is obtained by the rotation of the wave stirrer **34**, but this does not substantially improve the power distribution in the oven cavity **20** and in the load.

[0005] U.S. Pat. No. 5,204,503 discloses a microwave oven, wherein the microwave feeding system comprises a magnetron, a rectangular waveguide and a cylindrical cavity. A rotatable antenna and an inner cavity are arranged inside the cylindrical cavity. The waveguide extends horizontally. The cylindrical cavity is arranged beneath said waveguide.

[0006] FR 2 410 414 A1 discloses a microwave oven, wherein the microwave feeding system comprises a magnetron, a rectangular waveguide and a cylindrical cavity. A rotatable antenna is arranged inside the cylindrical cavity. The waveguide extends horizontally. The rotatable antenna is arranged above said waveguide.

[0007] It is an object of the present invention to provide a microwave feeding system for a microwave oven, which optimizes the power transfer from the magnetron to the oven cavity.

[0008] The object is achieved by the microwave feeding system according to claim **1**.

[0009] According to the present invention the magnetron, the rectangular waveguide and the cylindrical cavity are connected in straight series, wherein the microwave feeding system provides elliptically polarized TEM electromagnetic waves for the oven cavity, and wherein the omnidirectional antenna acts as a continuous phase shifter, and wherein an inner diameter of the cylindrical cavity is between 0.75 and three multiples of the wavelength of the microwaves guided within said cylindrical cavity.

[0010] The core of the present invention is the cylindrical cavity, the inner cavity and the shaft arranged coaxially to each other on the one hand and the arrangement of the magnetron, the rectangular waveguide and the cylindrical cavity in straight series on the other hand. The microwave feeding system increases the energy transfer to the oven cavity by the elliptically polarized electromagnetic waves. The uniformity and density of the power of the electromagnetic field in the oven cavity and in the load of said oven cavity is significantly improved. The efficiency of the real power absorbed by the load in relation to the microwave power delivered by the magnetron is more than 80%. The efficiency of the real power absorbed by the load in relation to the main power supply is about 60%. Thus, the power consumption is reduced.

[0011] Preferably, a Chebyshev waveguide transformer is interconnected between the rectangular waveguide and the cylindrical cavity.

[0012] In particular, the omnidirectional antenna is a quadrupole antenna and includes four blades.

[0013] For example, the blades of the omnidirectional antenna extend within one plane.

[0014] Further, the plane of the blades of the omnidirectional antenna may extend parallel to a longitudinal axis of the rectangular waveguide.

[0015] Moreover, the plane of the blades of the omnidirectional antenna may extend perpendicular to a the rotation axis of said omnidirectional antenna.

[0016] Preferably, the omnidirectional antenna and the shaft are formed as a single-piece part.

[0017] For example, the omnidirectional antenna and/or the shaft are made of metal, in particular made of stainless steel or aluminmium.

[0018] Preferably, an inner diameter of the cylindrical cavity is between 1.5 and two multiples of the wavelength of the microwaves guided within said cylindrical cavity.

[0019] Further, the rotation axis of the omnidirectional antenna may correspond with the symmetry axis of the cylindrical cavity. Thus, the omnidirectional antenna is in the centre of the cylindrical cavity. This results in symmetry of the output stage of the microwave feeding system.

[0020] In particular, the inner cavity is formed as a cylinder barrel, wherein preferably an inner diameter of the inner cavity is between 1.1 and five multiples, in particular between two and four multiples, of the diameter of the shaft enclosed by said inner cavity. In this case, the inner cavity has the same shape as the cylindrical cavity. This contributes to the symmetry of the output stage of the microwave feeding system.

[0021] Moreover, the microwave feeding system may comprise at least one choke filter arranged between the antenna motor and the cylindrical cavity.

[0022] Furthermore, the microwave feeding system may comprise at least one cover plate made of dielectric material and arranged or arrangeable between the cylindrical cavity and the oven cavity. The cover plate made of dielectric material protects the inner space of the cylindrical cavity on the one hand and lets pass the electromagnetic waves from the cylindrical cavity to the oven cavity.

[0023] Preferably, the rectangular waveguide, the Chebyshev waveguide transformer, the cylindrical cavity, the inner cavity and/or the choke filter are made of metal, in particular made of stainless steel and/or aluminium.

[0024] Further, the present invention relates to a microwave oven or an oven with microwave heating functions, wherein the microwave oven or the oven with microwave heating function, respectively, comprises at least one microwave feeding system mentioned above.

[0025] In particular, the microwave feeding system is arranged inside a wall of an oven cavity, preferably inside a top wall of said oven cavity.

[0026] Novel and inventive features of the present invention are set forth in the appended claims.

[0027] The present invention will be described in further detail with reference to the drawings, in which

[0028] FIG. **1** illustrates a schematic sectional side view of a microwave feeding system for a microwave oven according to a preferred embodiment of the present invention,

[0029] FIG. **2** illustrates a schematic sectional top view of the microwave feeding system for the microwave oven according to the preferred embodiment of the present invention,

[0030] FIG. **3** illustrates a schematic sectional side view of the microwave feeding system for the microwave oven according to the prior art, and

[0031] FIG. **4** illustrates a schematic sectional top view of the microwave feeding system for the microwave oven according to the prior art.

[0032] FIG. **1** illustrates a schematic sectional side view of a microwave feeding system **10** for a microwave oven according to a preferred embodiment of the present invention. In this example, the microwave feeding system **10** is arranged inside a top wall of an oven cavity **20**. In general, the microwave feeding system **10** may be arranged with an arbitrary wall of the oven cavity of a microwave oven or an oven with microwave heating functions.

[0033] The microwave feeding system **10** comprises a magnetron **12**, a rectangular waveguide **14**, a Chebyshev waveguide transformer **16** and a cylindrical cavity **18**. The magnetron **12** is connected to the rectangular waveguide **14**, wherein a magnetron antenna penetrates into the rectangular waveguide **14**. The Chebyshev waveguide transformer **16** is connected to the rectangular waveguide **14** and arranged opposite to the magnetron **12**. The cylindrical cavity **18** is connected to the Chebyshev waveguide transformer **16**. Thus, the magnetron **12**, the rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18** are connected in series. The rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18** are made of metal, for example stainless steel or aluminium.

[0034] A rotational omnidirectional antenna **22** is arranged inside the cylindrical cavity **18**. The rotation axis of the omnidirectional antenna **22** corresponds with the symmetry axis of the cylindrical cavity **18**. Since the microwave feeding system **10** is arranged inside a top wall of an oven cavity **20**, the rotation axis of the omnidirectional antenna **22** is vertical. In this example, the omnidirectional antenna **22** is a quadrupole antenna and includes four blades. The omnidirectional antenna **22** is driven by an antenna motor **24**. In this example, the antenna motor **24** is arranged above the cylindrical cavity **18**. A shaft **30** is interconnected between the antenna motor **24** and omnidirectional antenna **22**. The shaft **30** is made of a conductive material. For example, the shaft **30** and the omnidirectional antenna **22** are formed as a single-piece part. Preferably, the shaft **30** and the omnidirectional antenna **22** are made of metal, for example stainless steel or aluminium.

[0035] An inner cavity **26** is arranged inside the cylindrical cavity **18**. The inner cavity **26** is arranged coaxial to the cylindrical cavity **18**. Preferably, the inner cavity **26** is formed as a cylinder barrel. The inner cavity **26** encloses the shaft **30**. The inner cavity **26** and the shaft **30** are arranged coaxially to each other. The inner cavity **26** is made of metal, for example stainless steel or aluminium. Preferably, the inner diameter of the inner cavity **26** is between 1.1 and five multiples of the diameter of the shaft **30** enclosed by said inner cavity **26**. In particular, the inner diameter of the inner cavity **26** may be between two and four multiples of the diameter of the shaft **30** enclosed by said inner cavity **26**.

[0036] Further, a cover plate **28** is arranged between the cylindrical cavity **18** and the oven cavity **20**. Said cover plate **28** is made of a dielectric material. In particular, the cover plate **28** protects the omnidirectional antenna **22** and the inner cavity **26**.

[0037] Moreover, a choke filter **32** is arranged between the antenna motor **24** and the cylindrical cavity **18**. Said choke filter **32** has a cylindrical shape and is arranged coaxially to the cylindrical cavity **18**. The choke filter **32** avoids that microwave energy escapes through the antenna motor **24**.

[0038] FIG. **2** illustrates a schematic sectional top view of the microwave feeding system **10** for the microwave oven according to the preferred embodiment of the present invention. In particular,

[0039] FIG. **2** clarifies the arrangement of the magnetron **12**, the rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18**. Preferably, the inner diameter of the cylindrical cavity **18** is between 0.75 and three multiples of the wavelength of the microwaves guided within said cylindrical cavity **18**. In particular, the inner diameter of the cylindrical cavity **18** may be between 1.5 and two multiples of the wavelength of the microwaves guided within said cylindrical cavity **18**.

[0040] The magnetron **12** is connected to the rectangular waveguide **14**. The Chebyshev waveguide transformer **16** is connected to the rectangular waveguide **14** and arranged opposite to the magnetron **12**. In turn, the cylindrical cavity **18** is connected to the Chebyshev waveguide transformer **16**. The magnetron **12**, the rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18** are connected in series. In this example, the omnidirectional antenna **22** includes four blades. The inner cavity **26** is arranged coaxially to the cylindrical cavity **18**.

[0041] The microwave feeding system **10** of the present invention provides elliptically polarized TEM electromagnetic waves for the oven cavity **20**. The omnidirectional antenna **22** acts as a continuous phase shifter.

[0042] The inner cavity **26** acts additionally as a microwave choke filter, which avoids that microwave energy escapes to the antenna motor **24**. Further, the inner cavity **26** provides an attenuation of more than 90% for the main working frequency. Usually, the main working frequency of the magnetron **12** is 2.45 GHz.

[0043] The microwave feeding system **10** of the present invention increases the energy transfer to the oven cavity **20** by the elliptically polarized electromagnetic waves. The electric field vector extends parallel to the bottom wall of the oven cavity **20**. The uniformity and density of the power of the electromagnetic field in the oven cavity **20** and in the load of said oven cavity **20** is significantly improved. The efficiency of the real power absorbed by the load in relation to the microwave power delivered by the magnetron **12** is more than 80%. The efficiency of the real power absorbed by the load in relation to the main power supply is about 60%. Thus, the power consumption is reduced. The distribution of the microwave field in the oven cavity **20** is improved.

[0044] FIG. **3** illustrates a schematic sectional side view of the microwave feeding system **10** for the microwave oven according to the prior art.

[0045] The microwave feeding system **10** of the prior art comprises the magnetron **12**, the rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18**. The magnetron **12** is connected to the rectangular waveguide **14**. The Chebyshev waveguide transformer **16** is connected to the rectangular waveguide **14** and arranged opposite to the magnetron **12**. The cylindrical cavity **18** is connected to the Chebyshev waveguide transformer **16**. Thus, the magnetron **12**, the rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18** are connected in series. The rectangular waveguide **14**, the Chebyshev waveguide transformer **16** and the cylindrical cavity **18** are made of metal, for example stainless steel or aluminium.

[0046] A wave stirrer **34** is arranged inside the cylindrical cavity **18**. The rotation axis of the wave stirrer **34** corresponds with the symmetry axis of the cylindrical cavity **18**. The wave stirrer **34** is connected to the motor **24** via a stirrer shaft **36**. Said stirrer shaft **36** is made of dielectric material.

[0047] FIG. **4** illustrates a schematic sectional top view of the microwave feeding system **10** for the microwave oven according to the prior art. The wave stirrer **34** includes four stirrer blades. The wave stirrer **34** shifts the phase of the electromagnetic waves, but this is not sufficient for improving the microwave distribution, since there is a big variation of the impedance between the location point of the antenna of the magnetron **12** and the oven cavity **20**. This results in an efficiency of the power consumption of not more than 50% to 55%. The blades of the wave stirrer **34** reflect a part of the microwave energy back to the antenna of the magnetron **12**, so that an outer body of said magnetron **12** is heated up. The microwave feeding system **10** of the prior art generates only linearly polarized TE and TM electromagnetic waves resulting in a standing wave picture in the oven cavity **20**. Said electromagnetic waves are vertically and horizontally polarized. The only phase changing is obtained by the rotation of the wave stirrer **34**, but this does not substantially improve the power distribution in the oven cavity **20** and in the load.

[0048] Although an illustrative embodiment of the present invention has been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to that precise embodiment, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

LIST OF REFERENCE NUMERALS

[0049] **10** microwave feeding system
[0050] **12** magneton
[0051] **14** rectangular waveguide
[0052] **16** Chebyshev waveguide transformer
[0053] **18** cylindrical cavity
[0054] **20** oven cavity
[0055] **22** omnidirectional antenna
[0056] **24** antenna motor, motor
[0057] **26** inner cavity
[0058] **28** cover plate
[0059] **30** shaft
[0060] **32** choke filter
[0061] **34** wave stirrer
[0062] **36** stirrer shaft

1. A microwave feeding system for a microwave oven or an oven with microwave heating function, wherein:
- the microwave feeding system comprises a magnetron, a rectangular waveguide and a cylindrical cavity,
- the cylindrical cavity is connected or connectable to an oven cavity,
- a rotatable omnidirectional antenna is arranged inside the cylindrical cavity,
- the omnidirectional antenna is driven by an antenna motor,
- the omnidirectional antenna is connected to the antenna motor via a shaft made of conductive material,
- an inner cavity is arranged inside the cylindrical cavity,
- the inner cavity is arranged coaxially to the cylindrical cavity,
- the inner cavity encloses at least partially the shaft, and
- the inner cavity and the shaft are arranged coaxially to each other,

wherein the magnetron, the rectangular waveguide and the cylindrical cavity are connected in straight series, wherein the microwave feeding system provides elliptically polarized TEM electromagnetic waves for the oven cavity, and wherein the omnidirectional antenna acts as a continuous phase shifter, and wherein an inner diameter of the cylindrical cavity is between 0.75 and three multiples of a wavelength of microwaves guided within said cylindrical cavity.

2. The microwave feeding system according to claim **1**, wherein a Chebyshev waveguide transformer is interconnected between the rectangular waveguide and the cylindrical cavity.

3. The microwave feeding system according to claim **1**, wherein the omnidirectional antenna is a quadrupole antenna and includes four blades.

4. The microwave feeding system according to claim **3**, wherein the blades of the omnidirectional antenna extend within one plane.

5. The microwave feeding system according to claim **4**, wherein the plane of the blades of the omnidirectional antenna extends parallel to a longitudinal axis of the rectangular waveguide.

6. The microwave feeding system according to claim **4**, wherein the plane of the blades of the omnidirectional antenna extends perpendicular to a rotation axis of said omnidirectional antenna.

7. The microwave feeding system according to claim **1**, wherein the omnidirectional antenna and the shaft are formed as a single-piece part.

8. The microwave feeding system according to claim **1**, wherein an inner diameter of the cylindrical cavity is between 1.5 and two multiples of the wavelength of the microwaves guided within said cylindrical cavity.

9. The microwave feeding system according to claim **1**, wherein a rotation axis of the omnidirectional antenna corresponds with a symmetry axis of the cylindrical cavity.

10. The microwave feeding system according to claim **1**, wherein the inner cavity is formed as a cylinder barrel, wherein an inner diameter of the inner cavity is between 1.1 and five multiples of the a diameter of the shaft enclosed by said inner cavity.

11. The microwave feeding system according to claim **1**, further comprising at least one choke filter arranged between the antenna motor and the cylindrical cavity.

12. The microwave feeding system according to claim **1**, further comprising at least one cover plate made of dielectric material and arranged or arrangeable between the cylindrical cavity and the oven cavity.

13. The microwave feeding system according to claim **2**, wherein the rectangular waveguide, further comprising at least one choke filter arranged between the antenna motor and the cylindrical, the Chebyshev waveguide transformer, the cylindrical cavity, the inner cavity and/or the choke filter are made of metal.

14. A microwave oven or an oven with microwave heating function, comprising the microwave feeding system according to claim **1**.

15. The microwave oven or oven with microwave heating function according to claim **14**, wherein the microwave feeding system is arranged inside a wall of an oven cavity.

16. A microwave feeding system for a microwave oven or an oven with microwave heating function, said feeding system being disposed in a wall of an oven cavity and comprising:

a magnetron, a rectangular wave guide and a cylindrical cavity all made of metal and all connected in series, the magnetron having a magnetron antenna that penetrates into the rectangular wave guide,

a rotational omnidirectional quadrupole antenna arranged inside said cylindrical cavity and having a rotation axis corresponding with a symmetry axis of said cylindrical cavity, said antenna being driven by a motor arranged above the cylindrical cavity, a shaft interconnecting said motor and said antenna, said antenna and said shaft both being formed from metal, said antenna having four coplanar blades extending in a plane that is parallel to a longitudinal axis of said rectangular wave guide and perpendicular to said rotation axis, said antenna in operation being effective to act as a continuous phase shifter for microwaves in said cylindrical cavity, an inner diameter of said cylindrical cavity being 1.5-2 times a wavelength of said microwaves to be guided within said cylindrical cavity;

an inner cavity formed as a cylindrical metal barrel and arranged inside said cylindrical cavity, said inner cavity being coaxial to said cylindrical cavity and enclosing said shaft, an inner diameter of said inner cavity being 2-4 times a diameter of said shaft; and

a choke filter having a cylindrical shape and being arranged between said motor and said cylindrical cavity, said choke filter being coaxial to said cylindrical cavity;

wherein in operation the microwaves emanating from said cylindrical cavity into said oven cavity are elliptically polarized TEM electromagnetic waves whose electric field vector extends parallel to a bottom wall of the oven cavity;

and wherein in operation an efficiency of real power absorbed by a load within said oven cavity relative to microwave power delivered by the magnetron is more than 80%.

17. The microwave feeding system for a microwave oven or oven with microwave heating function according to claim **16**, wherein in operation an efficiency of said real power to a main supplied to said magnetron for generating said microwave power is about 60%.

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