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(54) RADIATION DEVICE, HEATING DEVICE, METHOD FOR MANUFACTURING A HEATING DEVICE, AND USE OF A RADIATION DEVICE

(57) The underlying invention is in particular directed to a radiation device (8) configured for dielectrically heating, in particular cooking, of one or more objects (37), such as foodstuff, with high frequency radiation (9) in the radio frequency range, and/or microwave frequency range in a cavity (7) of a heating appliance (35), in particular a cooking appliance (35), comprising:
- at least one solid state power amplifier module (4) with at least one input port (11) and at least one output port (12), the solid state amplifier module (4) configured for amplifying radio frequency and/or microwave frequency signals received at the input port (11), and for outputting the amplified radio frequency and/or microwave signals at the output port (12); and
- at least one antenna (6) coupled to the output port (12) of the solid state amplifier module (4) and at least configured for radiating radio frequency or microwave frequency radiation (9) based on the signals from the output port (12) of the solid state amplifier module (4),

the at least one solid state power amplifier module (4) and the at least one antenna (6) being integrated on a common printed circuit board layout (13).

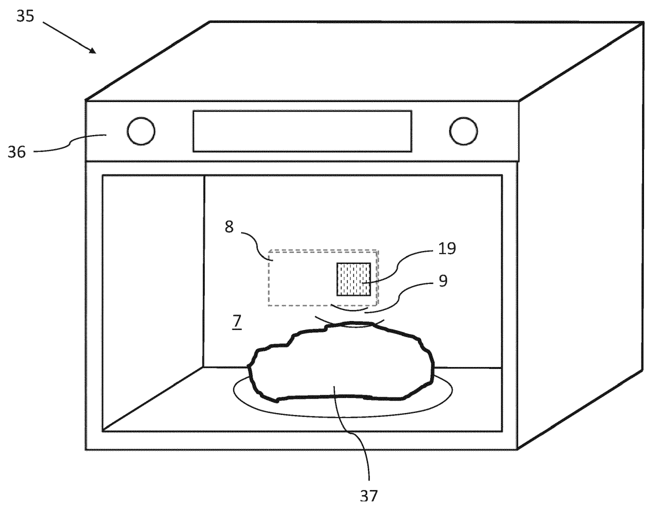

FIG. 9

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Description

Background

[0001] The present invention is directed to a radiation device for dielectrically heating, in particular cooking, one or more objects such as foodstuff, with high frequency radiation in the radio frequency and/or microwave frequency range, a heating device comprising a radiation device, a method for manufacturing a heating device, and a use of a radiation device.

[0002] Document EP 3 035 773 A1 describes a microwave appliance for cooking food, the appliance comprising a solid state microwave amplifier that is mounted to a heat sink. The appliance further comprises an antenna for emitting microwaves into a cavity for heating a food object. The antenna is mounted to one end of the heat sink, and may be directly wired to the amplifier. The given design is comparatively complex with regard to assembly.

[0003] Document US 5,558,880 A describes a microwave power radiator for microwave ovens with a patch antenna that is coupled to a heat sink. The patch antenna is connected via a strip line connector to a corresponding microwave oscillator. This suggested design is comparatively complex with regard to manufacture and assembly.

[0004] US 2017/0251530 A1 describes a microwave device for heating food objects, comprising a cavity, a microwave generator and two patch antennas. The patch antennas are provided at the bottom side of the cavity and connected via wire transmission lines, rectangular coaxial transmission lines or strip line transmission lines. Again, the assembly and manufacture may be comparatively complex.

Description of embodiments according to the invention

[0005] The objective technical problem may be considered as providing an improved radiation device, a heating device, a method for manufacturing a heating device, and a use of a radiation device the improvement related to simplified manufacture and assembly, and advantages with regard to cost and installation space. Further, a radiation device, a heating device, a method for manufacturing a heating device, and a use of a radiation device may be provided that are advantageous, in particular efficient, with regard to the generation and application of high frequency radiation in the radio frequency and/or microwave frequency range.

[0006] This object is solved by the features of each of the independent claims. Advantageous embodiments result from the dependent claims and the exemplary embodiments given below.

[0007] The invention is, in particular, directed to a radiation device, such as a radiation emitter device, configured for dielectrically heating, in particular cooking, one or more objects, such as food objects, food items, or foodstuff, with high frequency radiation in a cavity of a heating, in particular cooking, appliance. The heating/cooking appliance may be a microwave oven, or may be a combined oven appliance operable with different types for heating or cooking, such as radiant heating, convection heating, and dielectric heating, in addition to the possibility of heating via high-frequency radiation.

[0008] Within the technical meaning of the underlying invention, the term high-frequency (HF) radiation shall mean radiation suitable for dielectrically heating or cooking a food item or an item of food or foodstuff.

[0009] In particular, the high-frequency radiation may be in the radio frequency (RF) range, such as for example in the range from 1 MHz to 300 MHz.

[0010] Further, the radiation may be in the microwave frequency (MW) range, such as 300 MHz to 300 GHz.

[0011] As a note, the radiation device may be adapted such that the RF and MW radiation may be applied independent of each other. For example, the RF or MW radiation may be applied, at least in some operational phases, individually or, in other operational phases in combination, e.g. concurrently.

[0012] In embodiments, the radiation device may be configured for generating and emitting radiation in the RF range and/or in the MW range. In embodiments, the radiation device may be configured for generating and emitting radiation in the range covering RF and MW. For example, the radiation device may be configured for RF radiation and MW radiation, for example for covering different heating scenarios, e.g. thawing or defrosting (based for example on RF radiation), cooking (based for example in MW radiation), etc..

[0013] According to the invention, the ability of the radiation device to emit (or, in embodiments, to detect or receive) radiation in one or each of these radiation frequencies is expressed by the radiation device configured for dielectrically heating in the RF "and/or" MW range.

[0014] The radiation device, in particular a device at least configured for radiation emission, is configured for dielectrically heating, in particular cooking, one or more objects, such as foodstuff or items comprising foodstuff, with the object(s) located or placed in a cavity of a heating device, in particular cooking device, such as a cooking appliance. The radiation device may be configured for radiating the RF and/or MW radiation into the cavity. By this, the object(s) may be irradiated with the RF and/or MW radiation, causing heating by virtue of the object(s) absorbing the RF and/or MW radiation due to dielectric effects.

[0015] In this respect, the cavity may be configured for RF and/or MW heating or cooking. For example, the cavity may comprise walls made of a material or a compound material that is substantially impermeable for the RF and/or MW radiation. The material or compound material may comprise for example metal. In case that the walls defining the cavity are, at least in part, not impermeable for the radiation, an outer impermeable enclosure may be provided shielding the environment outside of the cavity from RF and/or MW radiation.

[0016] Specifically, the cavity may be configured for preventing RF and/or MW radiation radiated into the cavity from leaking outside. In this connecting, the cavity, and the cavity and enclosure, if required, may be considered RF and/or MW tight.

[0017] As mentioned above, the RF radiation is preferably in the range from 1 MHz to 300 MHz, and the MW radiation is preferably in the range from 300 MHz to 300 GHz. The RF and MW radiation and the RF and MW range may be selected such that foodstuff may be heated, e.g. thawed/defrosted, or cooked etc.. The mentioned ranges in particular are suitable for heating or cooking foodstuff.

[0018] The radiation device comprises at least one solid state power amplifier (SSPA) module or pallet, with at least one input port and at least one output port, the SSPA module configured for amplifying RF and/or MW signals received at the input port, in particular from a signal generator module, and for outputting the amplified RF and/or MW signals at the output port. The signal generator module may be part of the radiation device, or may be provided separately, with an output port thereof being connected to the input port of the SSPA module.

[0019] The radiation device further comprises at least one antenna coupled to the output port of the SSPA module. The antenna is at least configured for emitting (or: radiating) RF or MW radiation based on the signals from the output port of the SSPA module.

[0020] In embodiments, at least one of the at least one antenna may be configured and provided for use for receiving RF and/or MW radiation. In this case, the antenna may be connected to a receiver module configured for receiving the radiation from the antenna. The antenna may for example be used as a receiving antenna for determining the absorption characteristic of the object(s) placed in the cavity. In case that the absorption of the object(s) within the cavity is poor, considerable amounts of the radiation may be reflected, wherein the reflected radiation may be received and detected by the antenna and a corresponding receiver module, and the operation of the radiation device may be adapted to reduce, in particular minimize, reflection.

[0021] In case that the absorption of the radiation generated by the amplifier module is determined to be low or poor, in particular insufficient, the SSPA module or the signal generator module may be adapted to match the RF and/or MW radiation to the absorption characteristic of the object(s), for example to obtain maximum absorbance. In this regard, the SSPA module and/or the signal generator module may be configured for varying the RF and/or MW signals.

[0022] In the radiation device as suggested, the at least one SSPA module and the at least one antenna are integrated on a common, in particular a single, printed circuit board layout. As an example, the SSPA module and the antenna may be provided or implemented on a single printed circuit board (PCB).

[0023] The suggested radiation device, in particular the suggested printed circuit board layout, provide the advantage of simplified manufacture and installation. In particular, because the SSPA module and antenna may be manufactured for being handled as a single component during installation and mounting. In addition, the suggested design makes it possible to eliminate connectors (of any kind) on the SSPA module, because the antenna may be directly connected on the printed circuit board to the output port of the SSPA module. By this, it is in particular possible to eliminate coaxial cable or guide assemblies between SSPA module and the antenna. Without the need of connectors and/or cables etc. a more efficient transfer between the SSPA module and the antenna is possible, and leakage prevention in sections between the SSPA module and the antenna may be simplified.

[0024] Yet further, the suggested design enables a compact design, in turn simplifying integration into a heating or cooking appliance, such as a cooking oven, e.g. a household cooking oven.

[0025] Yet further, the suggested design is advantageous with regard to mass production and manufacturing cost, and/or system flexibility. In particular, the antenna may be implemented as a printed antenna on the PCB, and, in this respect, may be adapted with regard to emission characteristic, e.g. shape and structure, according to respective needs in a comparatively simple manner. For example, the shape and structure of the antenna may be adapted to the requirements of the cavity, which may vary dependent on the cavity shape and/or size, and/or on the frequency range used. In this respect, the radiation device may comprise more than one antenna, adapted to different requirements resulting from cavity shape and/or size, and/or the frequency range covered by the at least one SSPA module.

[0026] In embodiments, at least one of the at least one SSPA module and at least one of the at least one antenna are placed successively on a common or single PCB of the printed circuit board layout. In particular, an antenna input port of the antenna may be connected to and positioned immediately after or adjacent to the output port of the SSPA module. The SSPA module and the antenna may be placed on the PCB directly next to each other with the output port of the SSPA module facing the input port of the antenna. By this, signal transmission pathways may be kept as short as possible, in particular reduced to a minimum with the advantage of reducing transmission losses. Further, a compact design may be realized.

[0027] In embodiments, the radiation device may further comprise a housing accommodating therein at least the at least one SSPA module and the at least one antenna. The housing has an outer housing shell with a pass-through window, i.e. a window that is transparent for the HF radiation, i.e. the RF and/or MW radiation, such that the radiation emitted by the antenna can pass through the window.

[0028] The pass-through window is aligned with the position of the antenna in the housing and configured to permit HF radiation in the RF and/or MW range, in particular the HF radiation emitted by the antenna, to pass through. Except for the pass-through window, the housing, i.e. the housing shell, is non-transparent for the HF radiation in the RF and/or MW range. By this, the electronic components of the SSPA module and others may be shielded from the HF radiation generated and emitted by the antenna, whilst enabling the antenna to emit HF radiation to the outside. Specifically, the housing shell may be designed to surround the components of the SSPA module and other HF-sensitive components arranged in the housing. The pass-through window may be adapted to the size and active emission area of the antenna such that the antenna is able to emit the HF radiation substantially without absorption and/or distortion losses caused by the protective housing shell.

[0029] In embodiments, the housing is configured for attachment to a support element of the appliance, in particular to an outer side of a cavity wall of the cavity, to a support panel and/or to a component carrier of the appliance.

[0030] In embodiments, the housing and pass-through window may be configured for placement at a transparent opening of the cavity enabling feeding, in particular direct feeding, of the HF radiation emitted by the antenna into the cavity.

[0031] In particular, the housing of the radiation device as such and/or the support element may comprise fastening elements, in particular mutually matching fastening elements. The housing, the support element, and/or the fastening elements may be configured such that the antenna or the pass-through window can be aligned with the transparent opening of the cavity.

[0032] In embodiments, the housing, the support element, and/or the fastening elements may be configured such that the pass-through window is pushed against the transparent opening in the mounted state, such that HF radiation emitted by the antenna can be directly fed into the cavity, whilst avoiding leakage in or at the junction area between the housing of the radiation device and the cavity.

[0033] In embodiments, the attachment of the housing of the radiation device on or at the cavity, e.g. on or at a support element, may be configured such that the HF radiation may be fed into the cavity via a feed line, such as a wave guide or similar, interposed between the pass-through window and the transparent opening.

[0034] In view of this, the suggested radiation device is suitable both for directly feeding the HF radiation into the cavity and for indirectly feeding the HF radiation into the cavity via a feed line. Therefore, the suggested radiation device provides flexibility with regard to mounting and positioning the radiation device relative to the cavity and within an outer housing of the heating or cooking appliance.

[0035] In embodiments, the housing of the radiation device that accommodates the SSPA module may be made from a first material that is impermeable to the RF and/or MW radiation. Specifically, the housing may be made, at least in part, from an electrically conducting material, composition, or composite material. The first material may comprise or be metal, in particular sheet metal. The housing walls may be designed, by virtue of being electrically conducting, to shield the inner space accommodating electronic components, such as the SSPA module, from the HF radiation generated and emitted by the antenna.

[0036] Further, the pass-through window and the position of the antenna relative to the pass-through window may be selected such that the HF radiation emitted by the antenna is prevented from leaking into the interior of the housing.

[0037] In embodiments, the pass-through window may be implemented as a cutout.

[0038] The cutout may be filled or covered by a second material that is transparent for the RF and/or MW radiation.

[0039] In embodiments, at least one of the at least one antenna may be selected from the group comprising: patch antenna with microstrip feeding, patch antenna with aperture feeding, coplanar patch antenna, monopole microstrip antenna, in particular printed monopole antenna. In this connection, a patch antenna may be understood as an antenna having a flat surface such that it can be mounted on a corresponding flat or even surface, of the PCB for example. In embodiments, the patch antenna may have a planar rectangular, circular, triangular, or other shape, and may comprise a sheet or "patch" of metal. In embodiments, the patch may be mounted over a larger sheet acting as ground plane.

[0040] The type and/or shape of the antenna may be selected in dependence of the cavity (shape, size, etc.) used, the intended application (thawing, cooking, boiling etc.), and/or the RF and MW range, generator or amplifier used.

[0041] In connection with a patch antenna, the ground plane of the antenna may be directly placed on the PCB. In embodiments, the ground plane (or plate) may not be part of the PCB, but realized with a sort of "metal panel" behind the PCB.

[0042] In embodiments, the radiation device may further comprise a receiver module with an input port thereof connected to the antenna. The receiver module may be configured for receiving, via the antenna, RF and/or MW radiation reflected back from the cavity. The receiver module may be accommodated within the housing of the radiation device, and may be shielded by the housing from being radiated with the HF radiation generated by the antenna and/or reflected back from the cavity. In general, the housing of the radiation device, accommodating the amplifier module and other HF-sensitive electronic or electric components may be configured such that these components are shielded from being radiated with HF radiation generated by the antenna and/or reflected back from the cavity.

[0043] In embodiments, a heating device for dielectric heating, in particular cooking, one or more objects, such as foodstuff, with HF radiation in the RF and/or MW range is provided. The heating device may for example be a heating, in particular cooking, appliance, e.g. for use as a household device, for heating or cooking food, respectively.

[0044] The heating device comprises at least one radiation device according to any of the embodiments described in connection with the invention herein.

[0045] The hating device further comprises a cavity enclosed by outer walls, wherein the cavity is configured for accommodating therein the one or more objects to be heated by the HF radiation. Therefore, the cavity may be considered as a heating cavity configured for heating therein objects, in particular food, via dielectric heating based on HF radiation in the RF and/or MW range. As a note, in case that the radiation device is configured for generating RF radiation only, the cavity is accordingly adapted for RF heating, in particular such that at least RF radiation is prevented from leaking outside while enabling objects placed within the cavity to be heated by RF radiation. Similarly, if the radiation device is configured for generating MW radiation only, the cavity is accordingly adapted for MW heating, in particular such that at least MW radiation is prevented from leaking outside while enabling objects placed within the cavity to be heated by MW radiation. Finally, if the (one or more) radiation device(s) is(are) configured for generating both RF radiation and MW radiation (e.g. comprising respective amplifier modules), the cavity is accordingly adapted for RF and MW heating, in particular such that RF and MW radiation is prevented from leaking outside while enabling objects placed within the cavity to be heated by RF and MW radiation, respectively.

[0046] As mentioned, the outer walls of the cavity are impermeable for the RF and/or MW radiation. The outer walls, e.g. a particular wall of the cavity, such as a side wall, a bottom wall, a top wall, or a back wall, may and comprise at least one opening that is transparent for the RF and/or MW radiation, i.e. a transparent opening as referred to above. The opening may be configured such that RF and/or MW radiation emitted by a radiation device as described herein may be fed into the cavity for heating objects placed therein. The pass-through window of the radiation device may be aligned with the opening such that the RF and/or MW radiation can be fed directly into the cavity. In embodiments, a transmission line, such as a wave guide or coaxial line may be interposed between the pass-through window and the opening of the cavity for feeding the RF and/or MW radiation into the cavity.

[0047] The at least one radiation device may be positioned at, in particular mounted to, an outer side of an outer wall of the cavity such that the at least one antenna is able to emit RF and/or MW radiation through the opening into, in particular directly into, the cavity for heating the one or more objects.

[0048] In embodiments, the device may comprise more than one radiation device and corresponding openings in the cavity. For example, the radiation devices may be adapted to emit radiation in a particular frequency range, for example selected from RF or MW.

[0049] As such, one or more radiation devices may be configured and arranged for emitting RF radiation into the cavity, and one or more another radiation devices may be configured and arranged for emitting MW radiation into the cavity. Here, great flexibility with regard to heating food or foodstuff may be obtained, e.g. thawing, cooking etc., local heating/cooking, object- or food-specific heating etc..

[0050] Further, the HF heating may be combined with other known techniques such as radiant heating, convection heating etc.. In this connection, the heating device may be a combined heating device enabling several different heating modes (e.g. to be carried out concurrently) based on different types of heating, respectively.

[0051] In embodiments, the heating device may further comprise a RF and/or MW transparent inlay inserted into the opening of the cavity, or a RF and/or MW transparent cover connected to the wall and/or the opening of the cavity, and, respectively. The cover may cover the opening from an inner or outer side relative to the cavity interior.

[0052] As indicated above, a (conductive) gasket or similar may be arranged and positioned between the radiation device and the cavity. For example, the gasket may surround a transparent opening of the cavity and the pass-through window such that HF radiation may be prevented from leaking outside. Such a gasket may for example be made of a RF and/or MW impermeable material to avoid RF and/or RF leakage. The gasket may be adapted and configured for compensating planarity tolerances between the cavity wall, in particular between the opening, and the housing of the radiation device, in particular the pass-through window.

[0053] However, if the connection or linkage between the antenna and the cavity (i.e. the transmission passway between antenna, the pass through window, and the transparent opening in the cavity) is sufficiently tight, for example if the radiation device is screwed to the outer side of a cavity wall and the tolerances are sufficiently small, the radiation device, in particular the housing thereof, may be urged on the cavity wall such that the interconnection is sufficiently tight with regard to RF and/or MW leakage. In this case, the radiation device may be connected to the cavity wall without a gasket.

[0054] The transparent inlay may in embodiments be integrated between the antenna and the cavity, or can be added inside the cavity, so as to cover the antenna, in particular the pass-through window.

[0055] In general, the opening, may be configured to be dimensioned big enough such that the opening, in particular the border thereof, does not interfere with the radiation field defined by and associated with the antenna. This also applies to the pass-through window. The shape of the opening in the cavity and the pass-through window in this case, i.e. if there is no interference, may be substantially arbitrary. However, the shape of the opening and/or the pass-through window may be purposively selected based in the RF and/or MW radiation used, and/or based on the shape and dimensions of the cavity, the amplifier etc.

[0056] As mentioned, and according to embodiments, the heating device may further comprise a gasket that is impermeable for the RF and/or MW radiation and positioned between the opening in the cavity and the pass-through window. The gasket may be arranged and configured for preventing the RF and/or MW radiation from leaking outside in a contact area between the opening and the pass-through window. As mentioned, if the interface at the opening and the pass-through window is such that RF and/or RF is prevented from leaking out of the interface between the opening and the pass-through window, the radiation device may be mounted without such a gasket, e.g. directly to an outer cavity wall.

[0057] In embodiments, the heating device may further comprise a power supply unit, a signal generator module, a control unit, and a cooling module for cooling at least the radiation emitter device and other modules and units as required.

[0058] The power supply unit may be configured for supplying the signal generator module and the radiation emitter device with electric power. The signal generator module may be configured for generating RF or MW signals. An output port of the signal generator module may be coupled to an input port of the SSPA module for supplying the signals from the signal generator module to the SSPA unit. The control unit may be configured for controlling at least one of the power supply unit, the signal generator module, and the SSPA module, to emit the RF or MW radiation into the cavity for dielectric heating of the one or more objects placed therein.

[0059] In embodiments, the control unit may further be configured for controlling the emission of the RF and/or MW radiation for heating the one or more objects based on RF and/or MW radiation reflected back from the cavity and received by a receiver module via the antenna.

[0060] In embodiments, the heating device, in particular the radiation device, may be configured for varying the frequency of the RF and/or MW radiation. In such embodiments, the control unit may be configured for varying the frequency based on the reflected radiation received by the receiver module. Such a configuration has the advantage that the radiation emitted into the cavity may be adapted to the absorption characteristic of the objects placed in the cavity, in particular to optimize RF and/or MW absorption.

[0061] According to embodiments of the invention, a method for manufacturing a heating device according as described herein in connection with the invention is provided. The method may comprise the following steps:

a) providing a cavity with outer walls that are impermeable for RF and/or MW radiation, wherein the RF is in the range between 1 MHz and 300 MHz, and the MW is in the range between 300 MHz and 300 GHz, and wherein the cavity comprises an opening that is transparent for the RF and/or MW radiation; and

b) mounting a radiation device according any embodiment described herein in connection with the invention to or at an outer side of an outer wall of the cavity such that the opening is aligned with the pass-through window of the radiation device to enable the RF and/or MW radiation generated by the radiation device to be fed into the cavity, in particular directly into the cavity, via the antenna.

[0062] The advantage of the suggested method using the radiation device as proposed in connection with the invention is that the manufacture of the heating device may be simplified, in particular because the radiation device may be handled as a single unit and component part. Specifically, it is not required to mount the amplifier and the antenna in separate mounting steps. Further, in case that the heating device or appliance is configured for directly feeding the RF and MW radiation into the cavity, the manufacture may further be simplified because the installation of waveguides and other transmission lines between the source of the RF and/or MW radiation and the cavity is not necessary in this case.

[0063] In embodiments of the invention, a use of a radiation device according to any embodiments described in connection with the invention in a device for heating, in particular cooking, one or more objects of foodstuff by dielectric heating based on radio RF radiation in the range from 1 MHz to 300 MHz and/or MW radiation in the range from 300 MHz to 300 GHz generated by the radiation device and emitted by the antenna is provided.

[0064] The device may for example be a cooking device.

[0065] The suggested use in particular is suitable for providing the advantages described above in connection with the embodiments of the invention.

Brief description of the drawings

[0066] Exemplary embodiments and aspects of the underlying invention will in the following be described in connection with the annexed figures, in which:

FIG. 1 shows a schematic system overview of components of a heating device according to an embodiment;

FIG. 2 shows a top view of an exemplary radiation device;

FIG. 3 shows a top view of an exemplary circuit board layout of the radiation device.

FIG. 4 shows a patch antenna with microstrip feeding;

FIG. 5 shows a patch antenna with aperture feeding;

FIG. 6 shows exemplary aperture shapes for a patch antenna according to FIG. 5;

FIG. 7 shows a coplanar patch antenna;

FIG. 8 shows a monopole strip antenna;

FIG. 9 shows a cooking device according to an exemplary embodiment; and

FIG. 10 shows a flow chart of an exemplary method for assembling the cooking device according to FIG. 9.

Description of exemplary embodiments

[0067] FIG. 1 shows a schematic system overview of components of a heating device according to an embodiment. The heating device, which will be described in connection with an exemplary embodiment in connection with FIG. 9, comprises a control unit 1, a power supply unit 2, a signal generator module 3, a SSPA module 4, a cooling module 5 for cooling the SSPA module 4, an antenna 6, and a cavity 7. It shall be noted that the heating device, in particular a cooking device, may comprise further components and units. However, only such components have been mentioned that seem helpful in understanding the exemplary embodiments according to the invention and described in connection with the figures.

[0068] The control unit 1 is configured for controlling the operation of the other components, in particular the power supply unit 2, the signal generator module 3, the SSPA module 4, in connection with generating and radiating HF radiation in the RF and/or MW range into the cavity 7, and in case that the cooling module 5 is an active cooling module also the cooling module 5. The HF radiation 9 emitted into or radiated into the cavity 7 is schematically illustrated in FIG. 1 by a dashed arrow.

[0069] The power supply unit 2 is configured for supplying power to the signal generator module 3 and the SSPA module, and, if required, to the cooling module 5.

[0070] The signal generator module 3 is configured for generating HF signals in the RF and MW range. The RF range may be from 1 MHz to 300 MHz, and the MW range may be from 300 MHz to 300 GHz. It is to be understood, that the given ranges refer to maximal frequency ranges, wherein the signal generator module 3 may be configured for generating signals in subinterval ranges from the given maximal ranges as required.

[0071] The signal generator module 3 provides the HF signals at an output port 10 of the signal generator module 3, which is connected to an input port 11 of the SSPA module 4.

[0072] The SSPA module 4 amplifies the HF signals received at its input port 11 from the output port 10 of the signal generator module 3 and provides the amplified signals at an output port 12 of the SSPA module 4.

[0073] The output port 12 of the SSPA module 4 is connected to the antenna 6, which is configured for emitting HF radiation 9 in the RF and/or MW range based on the amplified signals provided at the output port 12 of the SSPA module 4.

[0074] The SSPA module 4 and the antenna 6 are part of a radiation device 8 as shown and described in an exemplary embodiment in more details in connection with FIG. 2 and FIG. 3.

[0075] The HF radiation 9 emitted by the antenna 6 is fed into the cavity 7 for dielectrically heating one or more objects, such as food objects, food items and foodstuff inside the cavity 7.

[0076] The SSPA module 4 and the antenna 6 of the radiation device 8 (and possibly also other components) are integrated on a common printed circuit board 13 as shown in FIG. 2 and FIG. 3. By this, the SSPA module 4 and the antenna 6 may be handled and mounted as a single component, thereby simplifying assembly of the heating device. Further, by this arrangement, losses and leakage of HF radiation may be reduced due to short transmission pathways.

[0077] The SSPA module 4 and the antenna 6 are placed successively, in particular directly next to each other, on the printed circuit board 13. The antenna input port 14 of the antenna 6 is connected to and positioned immediately adjacent to the output port 12 of the SSPA module 4.

[0078] In the example shown in FIG. 2 and FIG. 3, the antenna 6 is implemented as a patch antenna with microstrip feeding which is also shown in FIG. 4.

[0079] The radiation device 8 comprises a housing 15 as shown in FIG.2. The housing 14 accommodates therein the SSPA module 4 and the antenna 6. The housing is made from a HF impermeable material so as to shield the HF-sensitive electronic and electric components therein from the HF radiation 9 generated and emitted by the antenna 6.

[0080] The housing 15 has and is defined by an outer housing shell 16 enclosing therein the electronic and electric components, in particular the SSPA module 4.

[0081] The outer housing shell 16 has a pass-through window 17, which is implemented in the given example as a cutout. The pass-through window 17 is aligned with the position of the antenna 6 in the housing 15 and configured to permit the HF radiation to be emitted by the antenna 6 to pass through. The rest of the outer housing shell 16 is made from a material that is non-transparent, i.e. impermeable, for the HF radiation 9. The pass-through window 17 is sufficiently large and geometrically designed to avoid attenuation or distortion of the HF radiation 9 to be emitted by the antenna 6.

[0082] As shown in FIG. 2, the housing 15 is configured for attachment to a support element, such as a wall or support element, of the heating appliance. In the given example, the housing 15 comprises several attachment tabs 18 with through holes configured for screw attachment on or at the cavity 7.

[0083] The attachment tabs 18, or, in more general, attachment means, may for example be used for attaching the housing 15 to an outer side of a cavity wall of the cavity 7. Other ways for attachment are possible, in particular attachment to a support panel o to a component carrier of the appliance. Further, other attachment means than those shown in FIG. 2 may be provided.

[0084] The housing 15 and the pass-through window 17 are configured for placement at a transparent opening 19 of the cavity 7 as shown in FIG. 9. As may be derived from FIG. 9, the pass-through window 17 and the transparent opening 19 are mutually positioned such that the HF radiation 9 emitted by the antenna 6 can be radiated into the cavity 7 through the pass-through window 17 and the transparent opening 19. The mutual position and the placement of the radiation device 8 as shown in FIG. 9 is such that HF radiation 9 emitted by the antenna 6 can be fed directly into the cavity 7. By this, transmission losses may be avoided. However, transmission means between the pass-through window 17 and the transparent opening 19, such as waveguides or coaxial lines, may be provided, depending on the placement of the radiation device 8.

[0085] The housing 15 of the radiation device 8 and the pass-through window 17 are configured in the example shown in FIG. 9 such that the surface of the housing 15 is substantially planar and can be press-fitted on a corresponding planar, outer mounting surface of a cavity wall.

[0086] Further, the pass-through window 17 and the transparent opening 19 are adapted in size to allow substantial undisturbed transmission of the HF radiation 9 into the cavity 7.

[0087] The housing 15 of the radiation device 8 may for example be made from metal, in more general from a material suitable for shielding the HF radiation 9. The pass-through window 17 may be implemented as a cutout, which may be filled or covered with a HF transparent material, if required.

[0088] The radiation device 8 may comprise different types of antenna 6, depending, for example, on the desired application, the HF radiation used, the size and dimensions of the cavity 7 and others.

[0089] In particular, the antenna 6 may be implemented as a patch antenna with microstrip feeding as shown in FIG. 4, a patch antenna with aperture feeding as shown in FIG. 5, a coplanar patch antenna as shown in FIG. 7, and a monopole microstrip antenna as shown in FIG. 8, which are generally known in the art.

[0090] As mentioned, the type and particular shape of the antenna 6 may be selected according to respective needs, e.g. depending on the particular cavity, application, and/or HF frequency used.

[0091] The antenna 6 shown in FIG. 4 represents a patch antenna with microstrip feeding with a planar active surface 20 and a microstrip feed 21.

[0092] The antenna 6 shown in FIG. 5 represents a patch antenna with aperture feeding, wherein the aperture 22 in the given example is rectangular in shape. The patch antenna of FIG. 5 is multilayered and comprises a feed layer 23 for feeding the HF signals from the output port of the SSPA module 4, an aperture layer 24 including the aperture 22, and a radiation layer 25 for radiating and emitting the HF radiation 9 via patch 26. The aperture 22 represents a coupling slot between the radiation layer 25 and a feed line 23a of the feed layer 23.

[0093] The HF radiation 9 emitted by the antenna 6 in FIG. 6 is inter alia dependent on the shape of the aperture 22. The aperture 22 shown in FIG. 5 is rectangular. However, other shapes may be used, depending on the particular application, e.g. defrosting, cooking, boiling, etc., cavity 7, in particular shape and size of the cavity 7, and/or HF frequency used.

[0094] FIG. 6 shows several different shapes that may be used for the aperture 22 of the patch antenna in FIG. 5. As shown in the upper row in FIG. 6, the aperture 22 may be rectangular with different sizes in length and width dimension. As shown in the lower row, the shape may also be different from rectangular, for example H-shaped, butterfly-shaped with sharp edges, or butterfly-shaped with rounded edges. As a note, the form, shape and size may be selected according to the particular application and cavity used.

[0095] FIG. 7 shows an antenna 6 implemented as a coplanar patch antenna with a layered design. The coplanar patch antenna of FIG. 7 comprises several ground plates 27, an upper substrate layer 28 and lower substrate layer 29, an antenna patch 30 associated with feed strip 31. The ground plates 27 may be made of a conducting material, and the substrate layers 28, 29 may be made from a low-k dielectric insulating material, in particular exhibiting weak polarization when subjected to an externally applied electric field.

[0096] FIG. 8 shows an antenna 6 implemented as a monopole microstrip antenna with a ground plane 32, a microstrip feed line 33, and a meandered monopole 34. The monopole may have a different shale in other embodiments.

[0097] The antennas 6 shown in connection with FIG. 4 to 8 are merely some examples. As indicated above, the antennas may be configured differently, in particular with regard to type, shape, number of layers etc..

[0098] The ground planes, as far as present in an antenna design, may be directly placed on the printed circuit board 13 of the radiation device 8. It is, however, also possible, that the ground plane is not part of the printed circuit board 13, but realized with a sort of "metal panel" on a side of the printed circuit board 13 that is averted from the antenna patch.

[0099] FIG. 9 shows a microwave oven 35 as an example for a heating device according to the invention. The microwave oven 35 comprises a control panel 36, the cavity 7, and the radiation device 8. The microwave oven 35 comprises a door (not shown) for closing the cavity 7 in the operational state in which a food item 37 placed within the cavity 7 is subjected to HF radiation 9 (only schematically indicated) for dielectrically heating the food item 37.

[0100] As shown in FIG. 9, the radiation device 8 is placed at a rear wall of the cavity 7 with the pass-through window 17 aligned with the transparent opening 19, such that HF radiation 9 emitted by the antenna 6 can be directly radiated into the cavity 7 for heating the object 37. As a note, the radiation device and transparent opening 19 may be placed at any other location and side wall of the cavity 7. Further, several of the radiation devices 8 may be provided at different locations at or on the cavity walls. Such radiation devices may of same type, or may be different, for example with regard to power, frequency range and others. In particular, the microwave oven 35, or in general a corresponding heating device, may comprise several radiation devices 8 for radiating HF radiation 9 into the cavity. Some of the radiation devices, or all of them, may for example have the same radiation spectrum. It is, however, also possible, that some of the radiation devices are adapted for particular applications. In particular, a radiation device may be provided that is adapted for heating the object 35 for defrosting or thawing, e.g. with a HF spectrum in the RF range. Further, a separate radiation device 8 may be provided that is adapted for cooking, e.g. with a HF spectrum in the MW range. However, a radiation device may be adapted and suitable for radiating both RF and MW as needed. If there are several radiation devices, they may be associated with different sections of the cavity 7 such that different volumes of the cavity 7, in particular different objects or food items placed within the cavity 7, may be heated differently. In addition, the radiation devices may be adapted for operating at variable frequencies, for example allowing frequency sweeping or adaption according to particular needs.

[0101] The transparent opening 19 may be covered by a transparent inlay inserted into the transparent opening 19, or it may be covered by a RF and/or MW transparent cover connected to the wall of the cavity 7, e.g. from an inner or outer side thereof. The cover may also or alternatively be attached, e.g. snap-connected to the transparent opening 19, for example in connection with an inner rim of the transparent opening 19. The cover covers the transparent opening 19, and may be adapted to seal the transparent opening 19 to avoid moisture from penetrating outwards in the area of the transparent opening 19.

[0102] FIG. 10 shows a flow diagram of method steps to be applied in a process for assembling a heating device, in particular the microwave oven 35 shown in FIG. 9.

[0103] The method comprises a step 101 of providing a cavity 7 with outer walls that are impermeable for RF and/or MW radiation in the range between 1 MHz and 300 MHz and in the range between 300 MHz and 300 GHz, respectively, wherein the cavity 7 comprises the transparent opening 19 that is transparent for the RF and/or MW radiation 9.

[0104] The method further comprises step 102 of mounting the radiation device 8 to or at an outer side of an outer wall of the cavity 7 such that the transparent opening 19 is aligned with the pass-through window 17 of the housing 15 of the radiation device 8 to enable the RF and/or MW radiation generated by the radiation device 8 to be fed into the cavity 7, in particular directly into the cavity 7, via the antenna 6 for dielectrically heating the object 37.

List of reference numerals

[0105]

1	control unit
2	power supply unit
3	signal generator module
4	SSPA module
5	cooling module
6	antenna
7	cavity
8	radiation device
9	HF radiation
10	output port of the signal generator module
11	input port of the SSPA module
12	output port of the SSPA module
13	printed circuit board
14	antenna input port
15	housing
16	outer housing shell
17	pass-through window
18	attachment tab
19	transparent opening
20	active surface
21	microstrip feed
22	aperture
23	feed layer
23a	feed line
24	aperture layer
25	radiation layer
26	patch
27	ground plane
28	upper substrate layer
29	lower substrate layer
30	antenna patch
31	feed strip
32	ground plane
33	microstrip feed line
34	meandered monopole
35	microwave oven
36	control panel
37	food item
101, 102	steps

Claims

1. A radiation device (8) configured for dielectrically heating, in particular cooking, of one or more objects (37), such as foodstuff, with high frequency radiation (9) in the radio frequency range and/or microwave frequency range in a cavity (7) of a heating appliance (35), in particular a cooking appliance (35), comprising:

    - at least one solid state power amplifier module (4) with at least one input port (11) and at least one output port (12), the solid state amplifier module (4) configured for amplifying radio frequency and/or microwave frequency signals received at the input port (11), and for outputting the amplified radio frequency and/or microwave signals at the output port (12); and
    - at least one antenna (6) coupled to the output port (12) of the solid state amplifier module (4) and at least configured for emitting radio frequency or microwave frequency radiation (9) based on the signals from the output port (12) of the solid state amplifier module (4),

    the at least one solid state power amplifier module (4) and the at least one antenna (6) being integrated on a common printed circuit board layout (13).

2. The radiation device (8) according to claim 1, wherein at least one of the at least one solid state power amplifier module (4) and at least one of the at least one antenna (6) are placed successively on a printed circuit board (13) of the printed circuit board layout (13), with an antenna input port (14) of the antenna (6) being connected to and positioned immediately adjacent to the output port (12) of the solid state amplifier module (4) .

3. The radiation device (8) according to claim 1 or 2, further comprising a housing (15) accommodating therein at least the at least one solid state power amplifier module (4) and the at least one antenna (6), the housing (15) having an outer housing shell (16) with a pass-through window (17), the pass-through window (17) aligned with the position of the antenna (6) in the housing (15) and configured to permit high frequency radiation (9) in the radio frequency and/or microwave frequency range, in particular high frequency radiation (9) emitted by the antenna (6), to pass through, wherein the housing (15), except for the pass-through window (17), is non-transparent for the high-frequency radiation (9) in the radio frequency and/or microwave frequency range.

4. The radiation device (8) according to claim 3, the housing (15) configured for attachment to a support element of the appliance (35), in particular to an outer side of a cavity wall of the cavity (7), to a support panel and/or to a component carrier of the appliance (35), and the housing (15) and pass-through window (17) configured for placement at a transparent opening (19) of the cavity (7) enabling feeding, in particular direct feeding, of the high frequency radiation (9) emitted by the antenna (6) into the cavity (7).

5. The radiation device (8) according to claim 3 or 4, the housing (15) being made of a first material that is impermeable to the radio frequency and/or microwave frequency radiation (9), such as metal, with the pass-through window (17) being implemented as a cutout.

6. The radiation device (8) according to claim 5, the cutout being filled or covered by a second material that is transparent for the radio frequency and/or microwave frequency radiation (9) .

7. The radiation device (8) according to any of claims 1 to 6, at least one of the at least one antenna (6) being selected from the group comprising: patch antenna with microstrip feeding, patch antenna with aperture feeding, coplanar patch antenna, monopole microstrip antenna.

8. The radiation device (8) according to any of claims 1 to 7, further comprising a receiver module with an input port connected to the antenna (6), the receiver module configured for receiving, via the antenna, radio frequency and/or microwave frequency radiation reflected back from the cavity (7).

9. A heating device (35) for dielectric heating, in particular cooking, one or more objects (37), such as foodstuff, with radio frequency and/or microwave frequency radiation (9), comprising:

    a) at least one radiation device (8) according to any of claims 1 to 8;
    b) a cavity (7) enclosed by outer walls, the cavity (7) configured for accommodating therein the one or more objects (37) to be heated, the outer walls being impermeable for the radio frequency and/or microwave frequency radiation (9), and comprise at least one opening (19) that is transparent for the radio frequency and/or microwave frequency radiation (9);
    c) the at least one radiation device (8) being positioned at, in particular mounted to, an outer side of an outer wall of the cavity (7) such that the at least one antenna (6) is able to emit radio frequency and/or microwave frequency radiation (9) through the opening (19) into, in particular directly into, the cavity (7) for heating the one or more objects (37).

10. The heating device (35) according to claim 9, further comprising a radio frequency and/or microwave frequency transparent inlay inserted into the opening (19), or a radio frequency and/or microwave frequency transparent cover connected to the wall and/or opening (19) and closing the opening (19).

11. The heating device (35) according to claim 10, further comprising a gasket that is impermeable for the radio frequency and/or microwave frequency radiation (9) and positioned between the opening (19) and the pass-through window (17), the gasket arranged and configured for preventing the radio frequency and/or microwave frequency radiation (9) from leaking outside in a contact area between the opening (19) and the pass-through window (17).

12. The heating device (35) according to any of claims 9 to 11, further comprising a power supply unit (2), a signal generator module(3), a control unit (1), and a cooling module (5) for cooling at least the radiation device (8), the power supply unit (2) configured for supplying the signal generator module (3) and the radiation device (8) with electric power, the signal generator module (3) configured for generating radio-frequency or microwave signals, with an output port (10) of the signal generator module (3) being coupled to an input port (11) of the solid state power amplifier module (4) for supplying the signals from the signal generator module (3) to the solid state power amplifier module (4), the control unit (1) configured for controlling the power supply unit (2), the signal generator module (3), and/or the solid state power amplifier module (4), to emit the radio frequency or microwave frequency radiation (9) into the cavity (7) for dielectric heating of the one or more objects (37) placed therein.

13. The heating device (35) according to claim 12, wherein the control unit (1) is further configured for controlling the emission of the radio frequency and/or microwave frequency radiation (9) for heating the one or more objects (37) based on radio frequency and/or microwave frequency radiation reflected back from the cavity (7) and detected by a receiver module of the heating device (35) via the antenna (6).

14. A method for assembling a heating device (35) according to any of claims 9 to 13, comprising:

a) providing (101) a cavity (7) with outer walls that are impermeable for radio-frequency and/or microwave frequency radiation (9), the radio frequency being in the range between 1 MHz and 300 MHz, the microwave frequency being in the range between 300 MHz and 300 GHz; the cavity (7) comprising an opening (19) that is transparent for the radio frequency and/or microwave frequency radiation (9); and

b) mounting (102) a radiation device (8) according to any of claims 1 to 8 to or at an outer side of an outer wall of the cavity (7) such that the opening (19) of the wall is aligned with a or the pass-through window (17) of the housing (15) of the radiation device (8) to enable the radio frequency and/or microwave frequency radiation (9) generated by the radiation device (8) to be fed into the cavity (7), in particular directly into the cavity (7), via the antenna (6).

15. Use of a radiation device (8) according to any of claims 1 to 8 in a device (35) for heating, in particular cooking, one or more objects (37) of foodstuff by dielectric heating based on radio frequency radiation (9) in the range from 1 MHz to 300 MHz and/or microwave frequency radiation (9) in the range from 300 MHz to 300 GHz generated by the radiation device (8) and emitted by the antenna (6) into a cavity (7) of the device (35), the device (35) preferably configured according to any of claims 9 to 13.

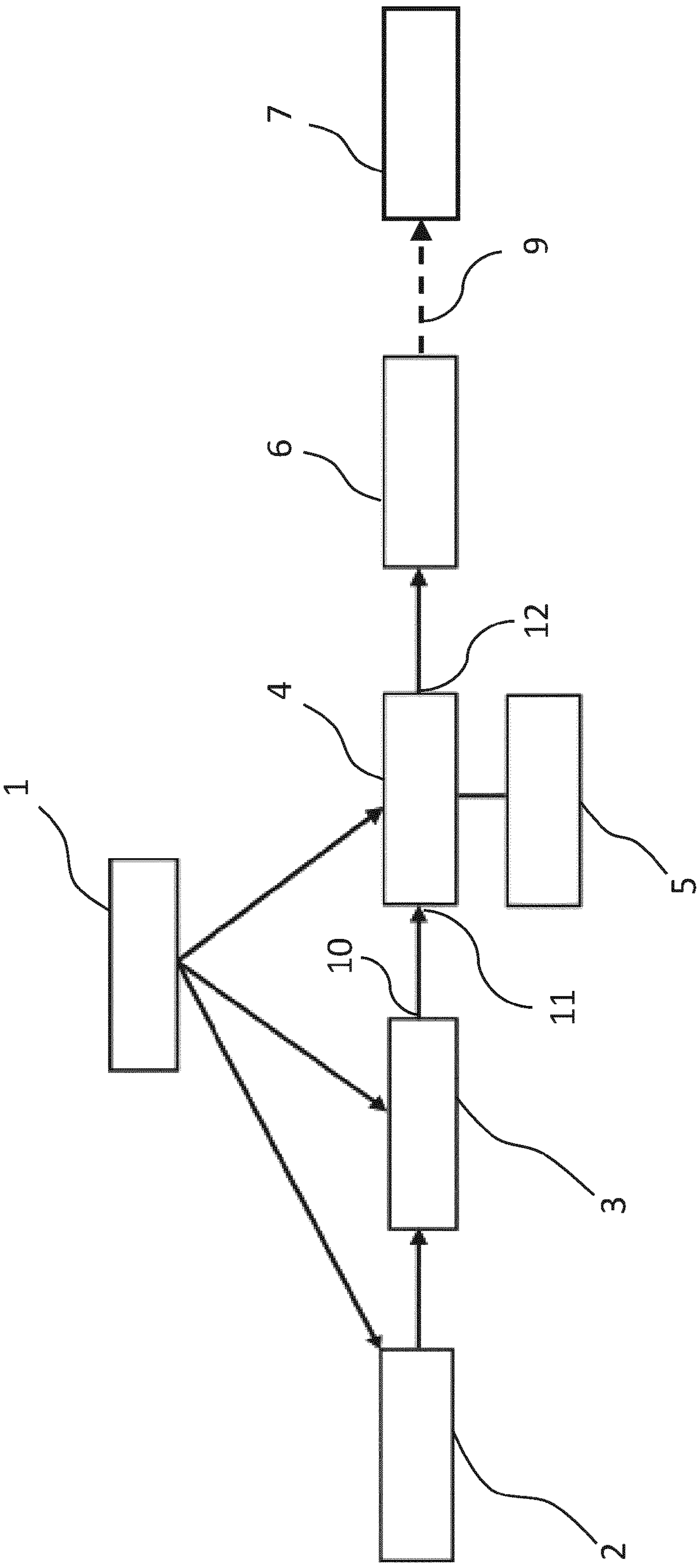
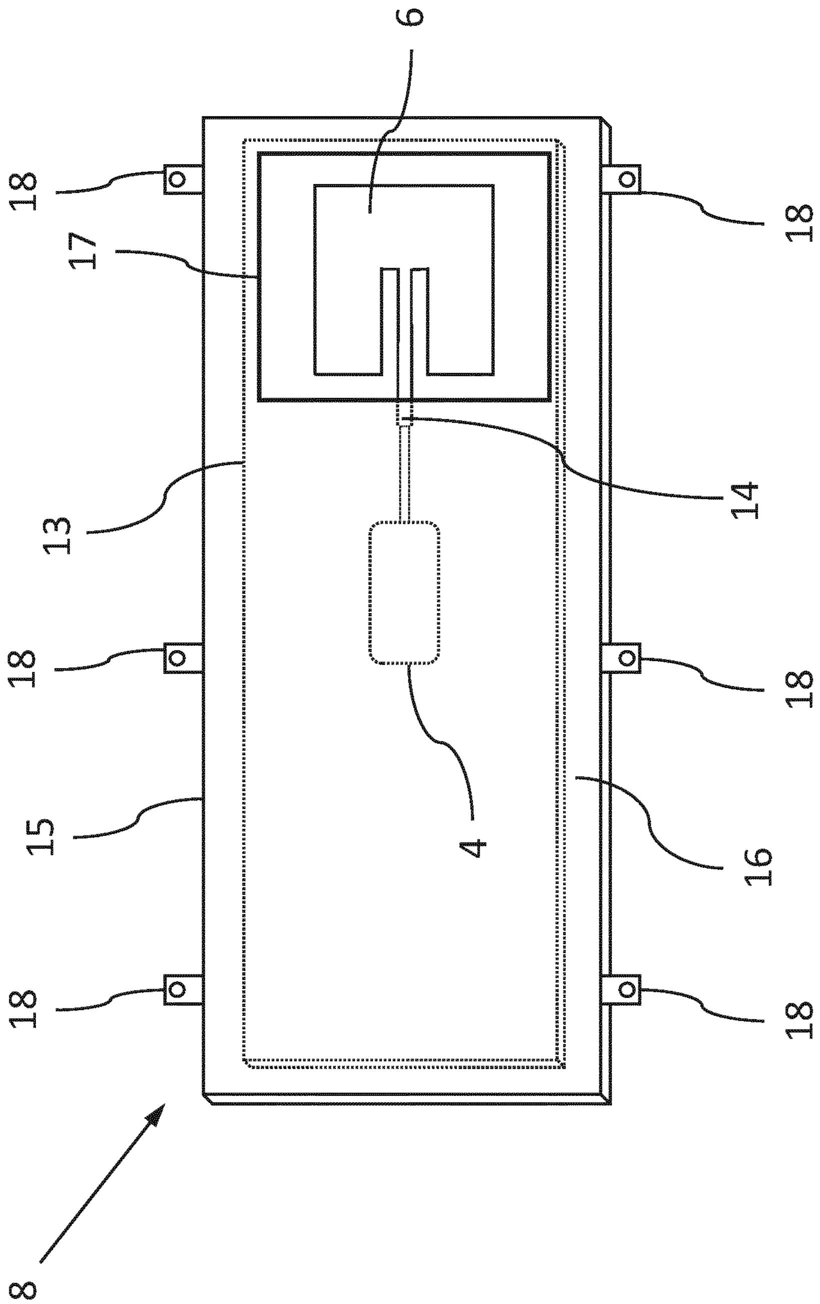


FIG. 1

FIG. 2



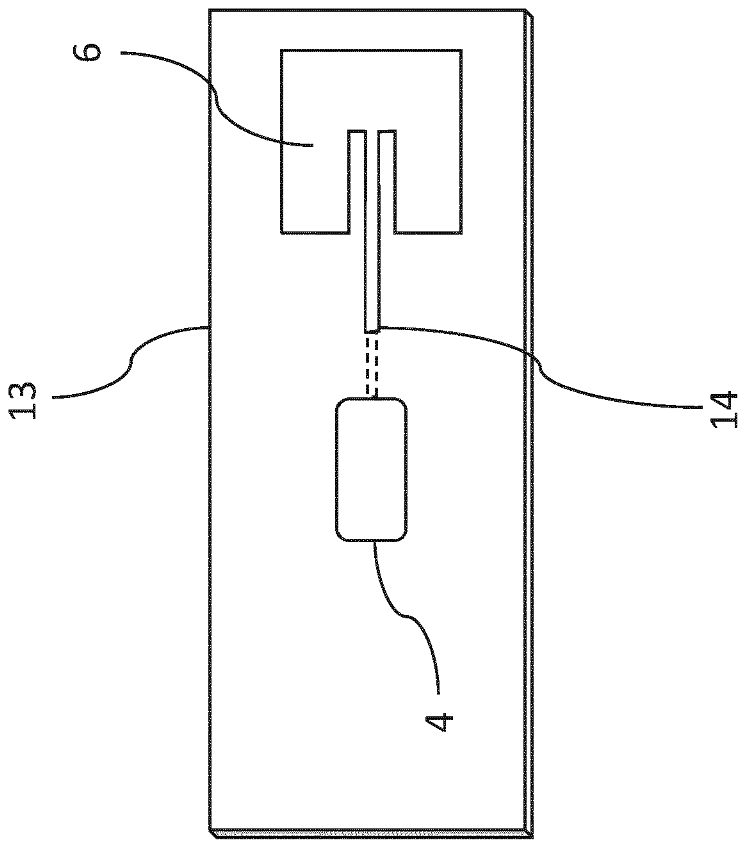


FIG. 3

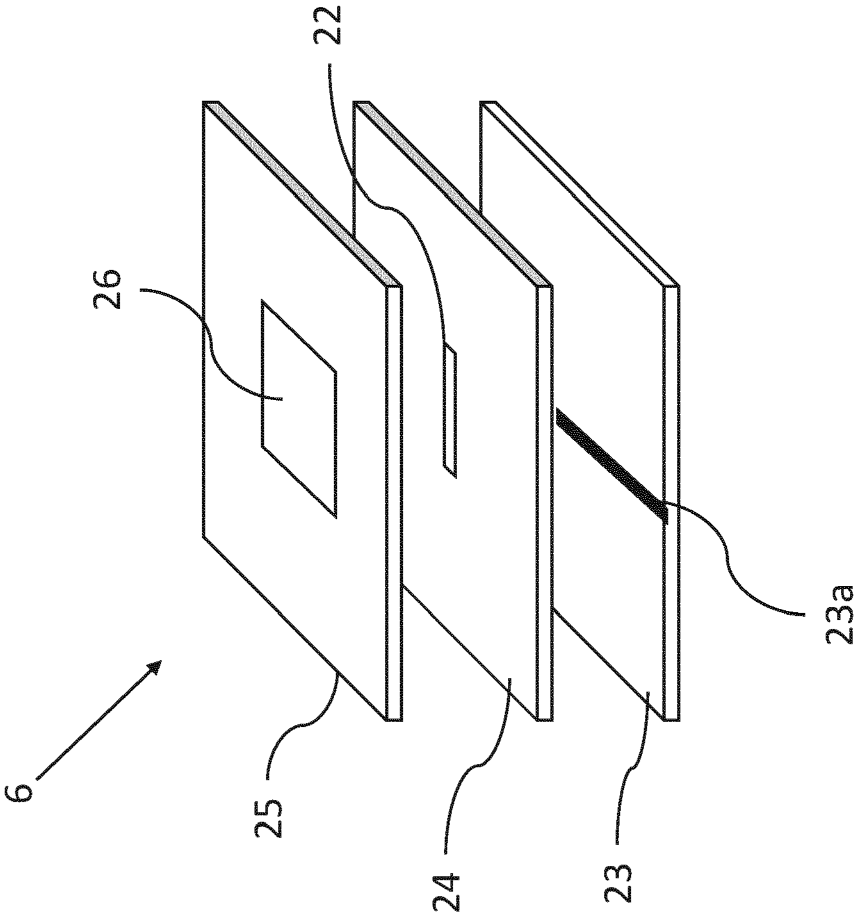


FIG. 5

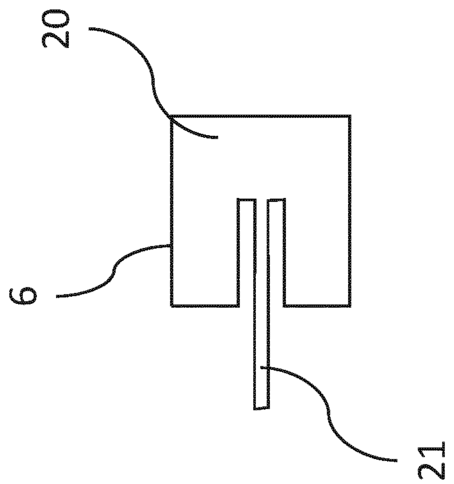
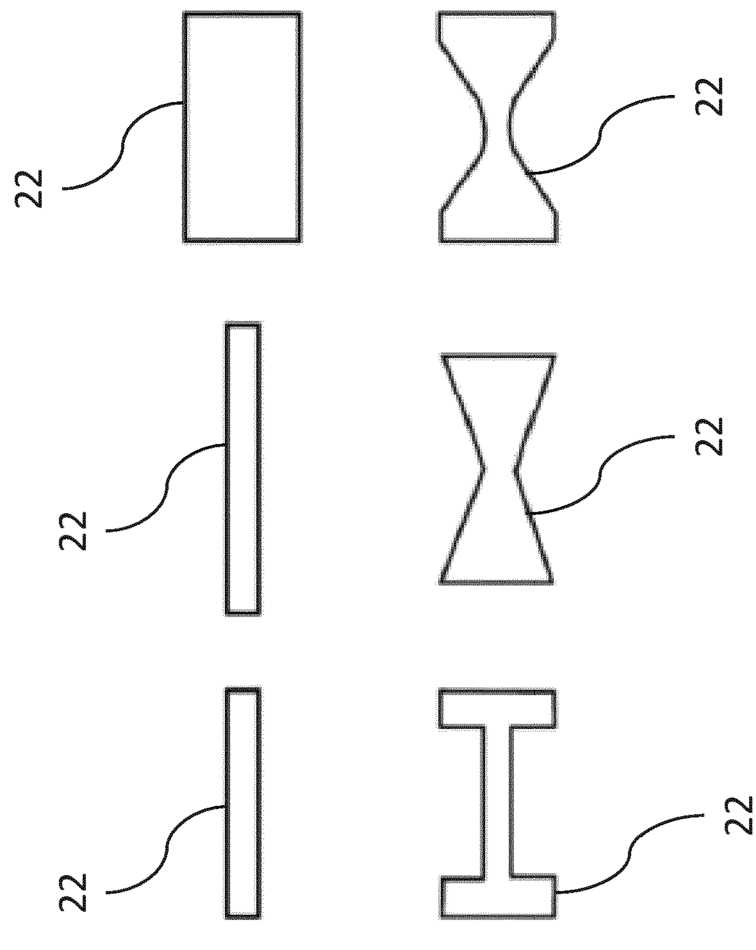


FIG. 4

FIG. 6



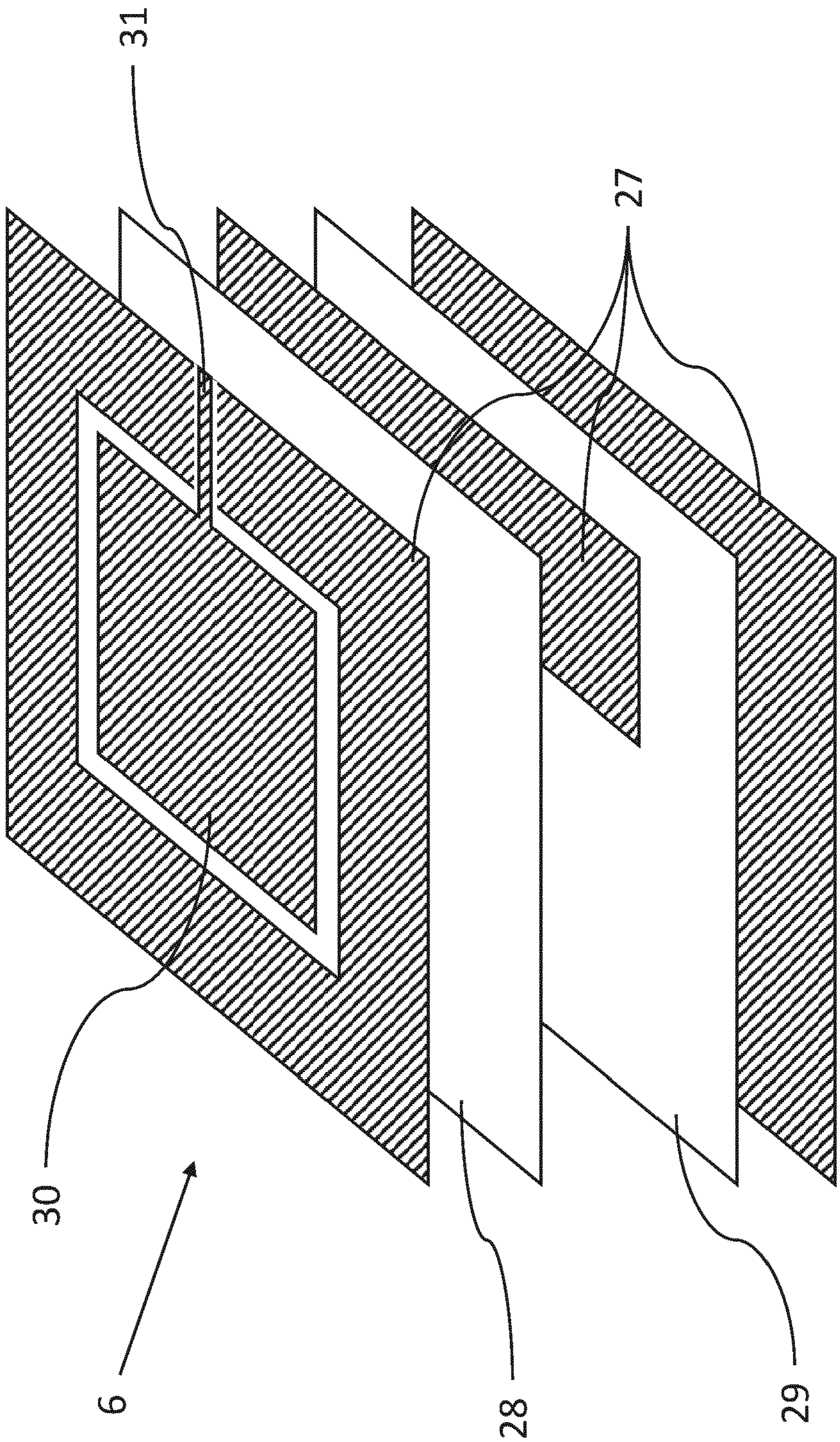


FIG. 7

FIG. 8

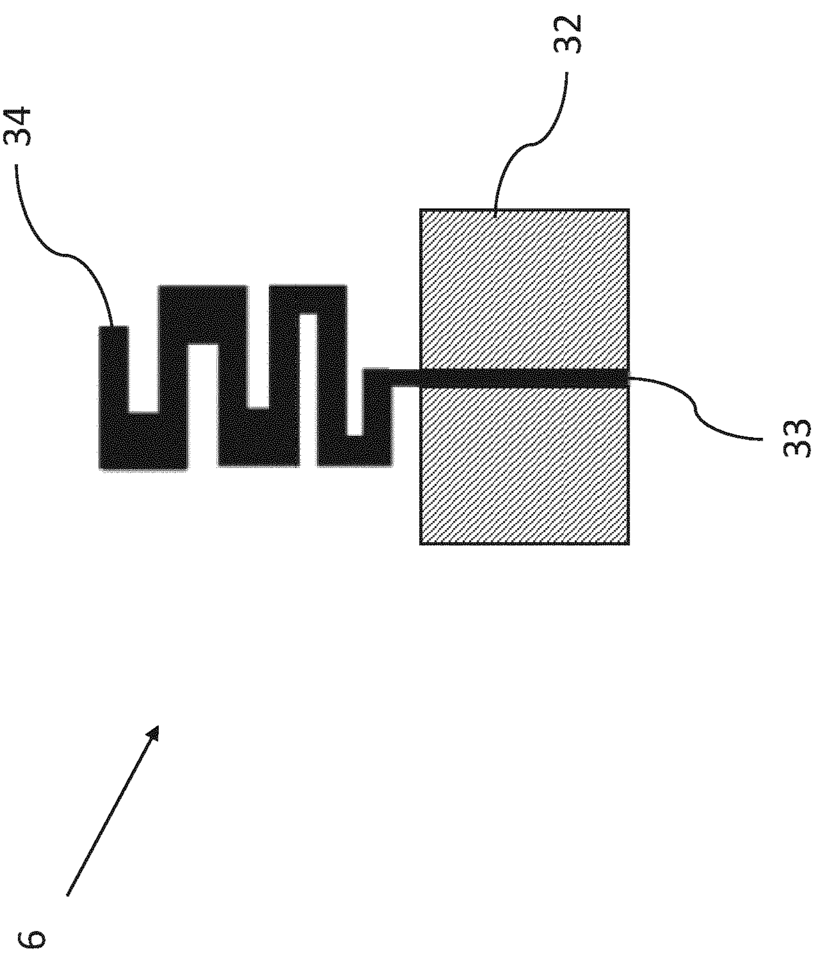
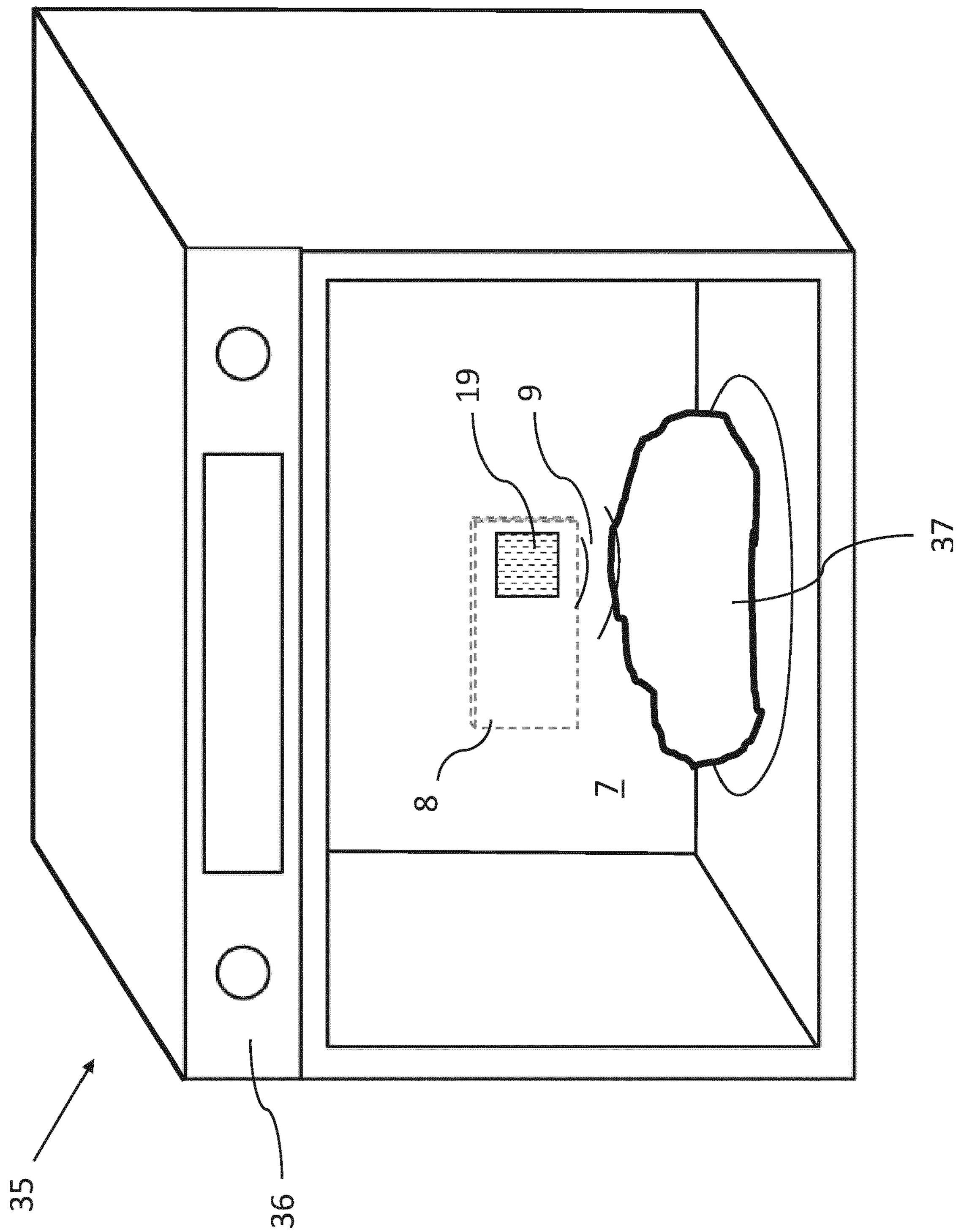


FIG. 9



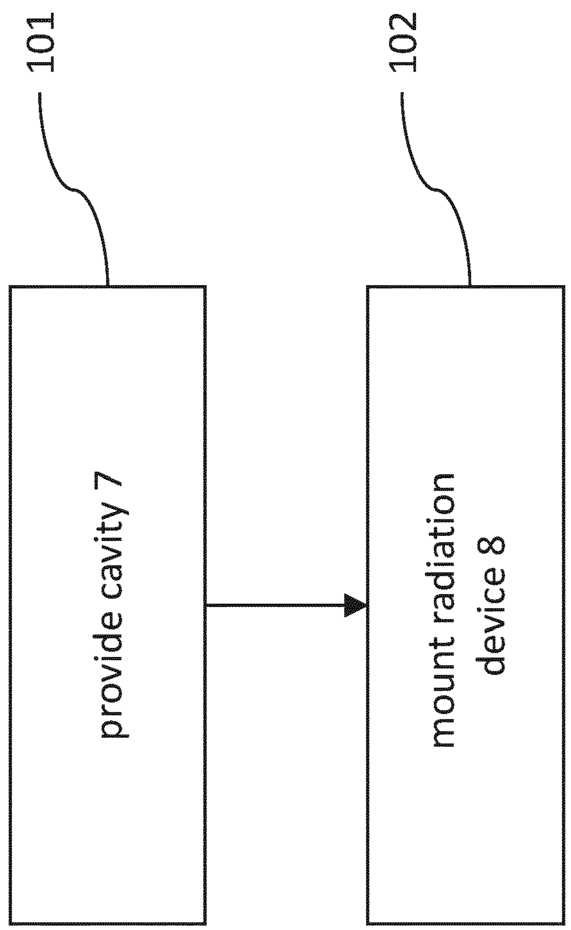


FIG. 10

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EUROPEAN SEARCH REPORT

Application Number
EP 21 15 2429

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2015/028839 A1 (FREESCALE SEMICONDUCTOR INC [US]; PIEL PIERRE MARIE [US] ET AL.) 5 March 2015 (2015-03-05) * abstract; claims 1-3,13,18; figures 1-6 * * paragraphs [0034] - [0036], [0039] - [0040], [0048], [0056] - [0063] *	1-15	INV. H05B6/68
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H05B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 June 2021	Garcia, Jesus

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17-06-2021

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