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(54) **METHOD OF OPERATING AN APPLIANCE, IN PARTICULAR HOUSEHOLD OR COOKING APPLIANCE, APPLIANCE, AND COMPUTER-PROGRAM PRODUCT**

(57) The underlying invention is directed to a method of operating an appliance (1), in particular household appliance (1), for defrosting (301, 302), in particular thawing (301, 302), a frozen object, in particular a frozen food object, placed in a treatment cavity (4) of the appliance (1). The method comprises the steps of heating (301) the

frozen object via capacitive radio frequency dielectric heating by supplying radio frequency power of a selected frequency or frequency range to the cavity (4); and at least temporarily during the capacitive radio frequency heating, supplying (302) aqueous steam into the cavity.

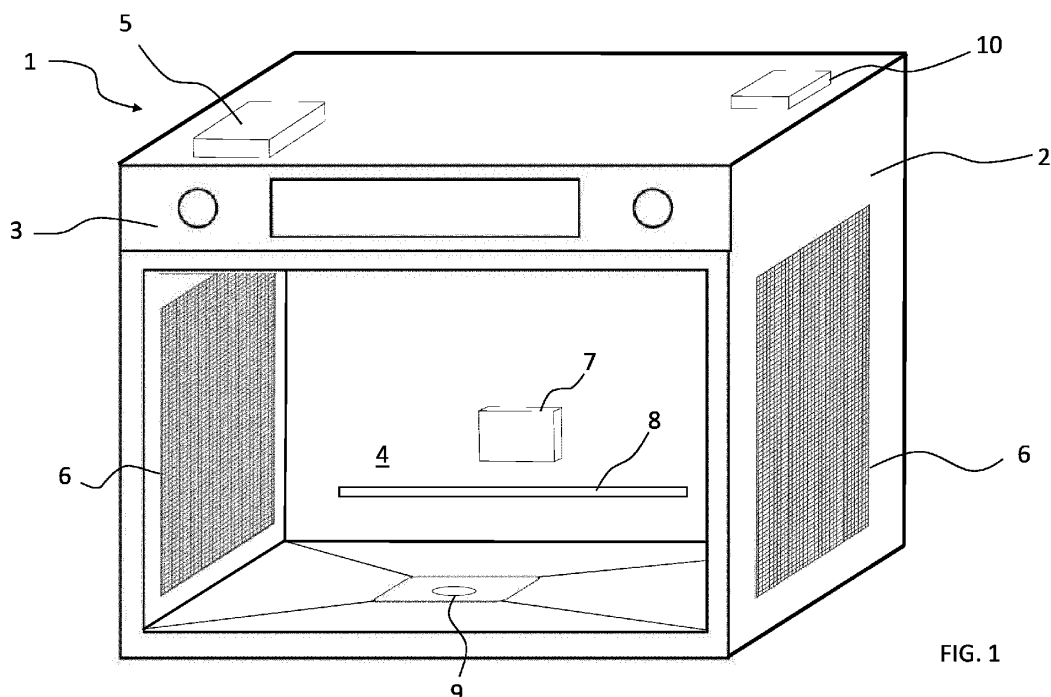


FIG. 1

Description

[0001] The present invention relates to a method and to an appliance, in particular a cooking appliance, for defrosting and/or cooking an object, in particular a food object.

[0002] According to current technology, radio frequency dielectric heating devices are known for defrosting food objects. Exemplary reference is made to EP 3 060 029 A1. This document describes a capacitive radiofrequency defrosting device using radio frequencies in the range from 1 MHz to 300 MHz.

[0003] Other possibilities for defrosting frozen food objects reside in using microwaves (in the range of for example 300 MHz to 300 GHz). However, microwave energy has, as compared to radio frequency energy, a comparatively small penetration depth. As a consequence, it may happen that the core of the food object is still frozen while the surface of the food object is overheated.

[0004] In view of this, it is an object of the invention to provide an improved method and an appliance for defrosting and for defrosting and cooking an object, such as a frozen food object. The invention in particular aims at obtaining a substantially uniform defrosting or thawing of the food object over its volume. Further, a possibility for automatically defrosting and for automatically defrosting and cooking an object, specifically a food object, shall be provided.

[0005] This object is obtained by the features of the independent claims. Embodiments result from the dependent claims and the below description of particular embodiments.

[0006] According to an embodiment, a method of operating an appliance, in particular a household appliance, for defrosting, in particular thawing, a frozen object, such as a food object, is provided. The method is for defrosting the (frozen) object that is placed in a treatment cavity of the appliance. The appliance may for example be an oven, such as a baking oven, having, in addition to a defrosting mode as suggested herein, a cooking mode for cooking the object. The term cooking shall be understood broadly in the sense of covering any known techniques for preparing a (food) object, including as baking, roasting, boiling, simmering etc.

[0007] The appliance is configured for perform defrosting process or a defrosting and cooking process for an object, in particular a food object. This shall in particular mean, that the appliance comprises a defrosting operational mode suitable for defrosting the object. For this, the appliance may comprise a defrosting unit comprising components as described herein in connection with defrosting and thawing. However, the appliance may also comprise a cooking operational mode, such that the appliance may be operated in the defrosting and/or cooking mode, i.e. in a defrost-only, or in a cook-only, or in a combined defrost and cook mode.

[0008] A food object shall be understood as comprising any kind and combination of foodstuff, which, in the or-

dinary consumable state (e.g. non-frozen, cooked state), comprises liquid, solid and/or pasty constituents.

[0009] As a general note, defrosting or thawing of an object shall imply that at least some parts or sections the object are in the frozen state, i.e. including partly or fully frozen objects, in particular food objects.

[0010] The method comprises at least the steps of:

a) heating the frozen object via capacitive radio frequency dielectric heating by supplying radio frequency (RF) radiation, in particular power, of a selected frequency or frequency range to the cavity; and

b) at least temporarily during the capacitive radio frequency heating, supplying aqueous steam into the cavity.

[0011] As indicated, "RF" will be used herein as an acronym for the expression "radio frequency".

[0012] The expression "at least temporarily during" in particular shall mean that the aqueous steam is supplied, at least over certain time periods, simultaneously with the RF heating. By this, the steam and radio frequency radiation may jointly act on the frozen food object in such time periods.

[0013] By at least temporarily supplying the RF radiation, in particular RF energy or RF power, and the steam to the cavity, and exposing the frozen object at least during certain time intervals or periods simultaneously with RF radiation and steam, improvements in energy and time efficiency for defrosting and thawing the object may be obtained.

[0014] On the one hand, the penetration depth of RF radiation is much greater as compared to microwave radiation. A larger penetration depth is advantageous in that surface overheating with the core of the object still being frozen, which quite often occurs with microwave defrosting, may be avoided. On the other hand, supplying steam to the cavity is suitable for homogenizing the absorption coefficient of the object, in particular food object, and for accelerating the defrosting and thawing process. In particular, the steam supplied to the cavity acts on the surface of the object, with the effect that the outer surface layer(s) of the object thaws first. Consequently, the outer layer(s) will absorb less RF energy, which is therefore conveyed further inside of the still frozen object.

[0015] Therefore, simultaneous applying RF radiation and steam to the object is suitable for improving and speeding up the defrosting and thawing process.

[0016] The term capacitive dielectric RF heating in particular relates to heating objects based on electromagnetic radiation having frequencies in the range from 1 MHz to < 300 MHz. Capacitive dielectric RF heating in particular is based on shifting polarized ions or molecules via the RF thereby raising the temperature. Capacitive dielectric RF heating may for example be obtained by using metal electrodes to form a kind of electric capacitor with the object to be heated being placed in the space

between the electrodes. By generating an alternating electromagnetic field with a frequency in the RF range between the electrodes, the RF radiation thus generated impinges on the object and will be absorbed by the object, heating or warming up the object.

[0017] As will be discussed further below, the absorption of the RF radiation is the higher, the better the RF radiation is tuned to the resonance frequency of the object. Such a tuning may for example be carried out based on a frequency or impedance sweep of a RF generator used.

[0018] The RF generator for generating the RF radiation to be supplied to the cavity may for example be a solid state RF generator, or a high-power RF amplifier based on triode technique or any other device for supplying RF radiation to a cavity of an appliance for defrosting an object.

[0019] The RF generator may be configured to supply a RF power in the range from 1 W to 2,000 W to the cavity, at least a RF power lying in a range suitable for thawing, in particular completely thawing, a frozen food product.

[0020] The food product may for example be or comprise one or more of water, milk, meat, vegetables, dough, etc..

[0021] In embodiments, the frequency of the RF radiation is selected to lie in the range of less than 300 MHz. In particular and advantageously, the RF lies in the range from 5 MHz to 50 MHz. Further, the RF may advantageously be selected to lie in a frequency band centered around one of the frequencies comprising 6.78 MHz (maximal bandwidth preferably 30 kHz), 13.56 MHz (maximal bandwidth preferably 14 kHz), 27.12 MHz (maximal bandwidth preferably 326 kHz), and 40.68 MHz (maximal bandwidth preferably 40 kHz). The mentioned frequencies and ranges or bands relate to so-called ISM frequency ranges or ISM frequency bands, reserved internationally for Industrial, Scientific and Medical (ISM) purposes other than telecommunications.

[0022] In embodiments, the method may further comprise a step of performing a RF sweep and/or impedance sweep for the cavity. Based on such a RF and/or impedance sweep, the RF radiation to be applied to the frozen object may be tuned to obtain appropriate, in particular maximal, absorption rates. In particular such a tuning may involve adapting the frequency of the RF radiation as such, the power level, the distance of electrodes provided for supplying the RF power to the cavity etc., in particular to maximize the amount of RF power that is absorbed by the object.

[0023] Under ordinary conditions, in particular if considering a frozen food product, and depending inter alia on the type, the consistency, the volume, the size, the distribution etc. of the object or parts thereof, a specific resonance frequency exists, within a given and used frequency range, for which the amount of power absorbed by the object is maximal. The RF generator may be adapted to emit RF radiation of a single frequency range of

band. Alternatively, the RF generator may be configured for setting or switching between different RF bands (centered around different RF frequencies as exemplarily given above, for example). For example, if in one RF frequency band the generator cannot be appropriately tuned to the resonance frequency of the object, the RF generator may switch the frequency band and try to obtain a better matching configuration with a higher absorption rate.

[0024] In general, maximizing the amount of absorbed RF power is desirable for enhancing the defrosting and thawing result, the speed, as well as the RF power consumption as such.

[0025] For this, embodiments of the method may involve a step of automatically determining a suitable operational condition for supplying the RF radiation to the cavity, in which the absorbed RF power or energy is at a maximum. Such a step may for example comprise the mentioned RF and/or impedance sweep in which the RF (e.g. the frequency as such, the phase, and/or the amplitude) and/or the impedance of a corresponding RF generator are modified, i.e. swept, over a predefined sweep range of frequencies (etc.) and impedances. At the same time, the RF power reflected back from the cavity may be measured, and based on the RF power supplied to the cavity and the reflected RF power, it is possible to determine the frequency and/or impedance where the absorbed RF power is at a maximum for the sweep range used, implying that the reflected RF power is at a minimum.

[0026] As indicated, such a frequency and/or impedance sweep, in particular for scanning the cavity for optimizing the operational parameters of the RF source (including a RF generator), may comprise the steps of:

b) supplying RF radiation within a predetermined RF sweep range and/or impedance sweep range to the cavity,

d) measuring the amount of energy supplied to and reflected back from the cavity over the RF sweep range and/or impedance sweep range;

e) determining a RF and/or impedance value within the RF and/or impedance sweep range for which the RF power absorbed within the cavity is maximized and/or for which the maximum RF power absorbed exceeds a predefined absorption threshold;

f) applying, in particular setting, the determined RF and/or impedance value for heating the object according to step a) of the method as described above.

[0027] For determining a suitable RF and/or impedance value for matching the resonance of the RF source or generator to the load, i.e. the object placed in the cavity, a predefined absorption threshold may be provided. The absorption threshold may for example be used for deter-

mining whether or not dielectric defrosting by using RF radiation has reached final stage and may be finished. For example, with increasing temperature of the object, i.e. with advanced defrosting or thawing, the dielectric properties of the object, i.e. a food object, change, in turn causing a change in the resonance frequency. When the temperature is or comes close to 0°C, the RF resonance curve, in particular in connection with ordinary food objects, becomes wide and the maximum power absorbed is much less as compared to the initial maximum power absorption in the still frozen state. This shift in the maximum power absorption may advantageously be used for controlling the defrosting or thawing process, wherein the condition in which the maximum power absorption falls below the absorption threshold, and for example reaches a plateau, may be identified as a stop condition for stopping RF-based defrosting or thawing.

[0028] In embodiments, the RF and/or impedance sweep, i.e. a scanning operation for scanning the cavity to identify an operational condition having, for the RF band or impedance band used, a respectively maximum RF power absorption, is carried out repeatedly during the defrosting or thawing process. Accordingly, an optimal RF setting and/or impedance setting may be obtained substantially throughout the defrosting or thawing process.

[0029] A corresponding method may involve repeatedly scanning the cavity based on a RF or impedance sweep, determining a RF and/or impedance value corresponding to the maximum power absorption, i.e. corresponding to the maximum RF power absorbed, and setting and using the impedance and/or RF frequency value for generating RF radiation used for defrosting.

[0030] A corresponding embodiment may therefore involve repeating the steps c) to e) as defined above at defined intervals, in particular at least once or more than once during the defrosting cycle.

[0031] Further, step f) as identified above, i.e. applying the determined RF and/or impedance value for defrosting the object, may be carried out if it is determined that the maximum RF power absorbed exceeds the predefined absorption threshold. In this case, exceeding the absorption threshold indicates that the defrosting has not finished yet any may be continued based on a RF value determined in accordance with the maximum RF power absorbed.

[0032] In case that it is determined that the maximum RF power absorbed is below the predetermined absorption threshold, at least the process of supplying the RF radiation for dielectric heating may be stopped. In an alternative, both the supply of RF radiation for defrosting and the supply of steam may be stopped if it is determined that the maximum RF power absorbed is below the predetermined absorption threshold. In this case, determining that the maximum RF power absorbed is below the predetermined absorption threshold may be used as an indication, in particular a trigger, that the defrosting or thawing process is not sufficiently efficient anymore and

can be stopped. At least such a determination may be indicative of a condition in which further supply of RF energy is or becomes inefficient, in particular with regard to the use of energy, for further defrosting, thawing or tempering.

[0033] In a further alternative, however, the method may, after stopping the supply of RF radiation, proceed with supplying only steam to the cavity, and correspondingly to the object, if it is determined that the maximum RF power absorbed is below the predetermined absorption threshold. As mentioned, in this case only the supply of the RF radiation is stopped, not however the supply of steam. This operational mode may be advantageous for tempering the object after the defrosting by the combined use of RF radiation and steam. In particular, appropriately thawed objects may be obtained, for example heated up or close to 0°C. Further, in cases or for certain food objects, in which the absorption of the RF radiation is impaired in the temperature range at or close to 0°C, for example, proceeding further with supplying only steam to the cavity may improve the defrosting result.

[0034] In embodiments, the defrosting, at least the step of supplying RF radiation to the cavity, may be stopped if a temperature of the object lies within a temperature range from -4°C to 0°C, in particular from -4°C to -2°C. The temperature may be measured and/or estimated via a temperature probe and/or based on reflected RF signals. Reflected RF signals, may for example be monitored during the defrosting process, and, for example based on an initial calibration, a temperature value may be determined from the monitored reflected RF signals. As an example, the absorption rate of the RF radiation signals decreases with increasing temperature of the frozen object. Thus, if the absorption or resonance curve becomes wide and the maximum RF power absorbed is much less as compared to an initial value, it may be determined that the temperature is for example close to or at 0°C, and that defrosting can be stopped.

[0035] Continuing with supplying steam to the cavity after stopping the supply of RF radiation to the cavity may involve a step of supplying steam for at least one of a predetermined and a predicted time interval. As such, a predetermined time interval may be associated with using a fixed time interval irrespective of the course of the defrosting process. Further, the time interval may be based on the respectively actual defrosting process, e.g. the duration, the power applied, the amount of steam supplied to the cavity, the size and type of object, etc.. For example, a large object may involve a longer defrosting cycle, and correspondingly the additional supply of steam after stopping the RF radiation supply may be elongated. This means that the time for supplying only the steam at the end or a final stage of the defrosting may be dependent on, e.g. proportional, to the time period during which the RF radiation was applied for defrosting purposes.

[0036] A predicted time interval may for example be

based on a temperature measurement of the object, e.g. by using a temperature probe, or other progress and process parameters, such as defrosting time, size, weight etc. of the object. In particular, a temperature measurement at the point of time of stopping the RF radiation supply may be used for predicting or estimating a time needed for heating the object to a desired final defrosting or thawing temperature, or for tempering the object to reach a final state, based on supplying only steam to the cavity in a final defrosting stage or phase.

[0037] Having reached the defrosted or thawed state, the object, in particular the food object, may be subjected to a heating, in particular cooking, procedure. The heating/cooking procedure may be carried out, in particular started, automatically after the defrosting cycle. During the heating/cooking procedure, the state of the object and/or cavity may be scanned by using the radio frequency, or by using any other type of electromagnetic radiation, such as light, microwave radiation (e.g. in the range from 300 MHz to 300 GHz), to determine a heating/cooking progress parameter related to the object. Microwave radiation may be used for heating/cooking the object subsequent to the defrosting or thawing process.

[0038] In embodiments, the method may further comprise draining condensed aqueous steam, i.e. liquid, from the cavity. By removing condensed aqueous steam from the cavity, the efficiency of the supplied RF energy for defrosting or thawing the object may be improved. In particular, wasting RF energy supplied to the cavity by warming condensed aqueous steam, e.g. liquid, in particular water, accumulated for example at the bottom wall of the cavity may be avoided, at least however greatly reduced.

[0039] Condensation of the aqueous steam may occur at the cavity walls, at the object, and/or at vessels, such as cookware, and the condensed aqueous steam may run-off or drop down and collect at the bottom wall of the cavity. For the reason that the RF energy or power supplied to the cavity acts substantially all over the cavity interior, the RF energy may also act on and be absorbed by the condensed aqueous steam or other liquids accumulating within the cavity, thereby reducing the RF energy or power available for defrosting or thawing the object.

[0040] In embodiments, the condensed aqueous steam is drained via a drain provided, for example, in the bottom, e.g. in the bottom wall of the cavity. The drain may comprise or be implemented as a drain opening in the bottom wall, for example. The drain opening may be associated, in particular implemented, in connection with a depression, sump, groove, or similar. In particular, the bottom wall, or at least sections of the bottom wall may be inclined towards the drain opening such that drainage of the condensed aqueous liquid collecting at the bottom wall may be improved. The drain opening may be provided with a closure or lid for opening and closing the drain opening.

[0041] According to embodiments, the drain opening may be open or opened throughout the whole defrosting

or thawing cycle. In alternatives, the drain opening may be opened at particular points of time during the defrosting or thawing cycle, for example repeatedly over the defrosting or thawing cycle. Further, a drain sensor for sensing the amount of condensed aqueous liquid or a level of condensed aqueous steam, in particular the amount of liquid, accumulated at or in the drain opening, e.g. in the sink or depression, may be provided. For example, if it is sensed by a corresponding sensor that the accumulated condensed aqueous liquid exceeds a certain amount or level, the drain opening may be opened by opening the lid or closure for draining dispensable condensed aqueous steam or other liquids. Thereafter, the closure or lid may be closed again, and the dispensing cycle may be started anew. Determining that surplus liquid may be drained from the cavity may also be determined based on a scan of the cavity, for example with RF radiation or other.

[0042] Providing a closure or lid may be advantageous for preventing the aqueous steam from directly exiting the cavity through the drain opening. Thus, closing the drain opening during predetermined phases during defrosting or thawing by applying steam to the cavity may increase the degree of efficiency of the aqueous steam, whilst draining the condensed aqueous steam at predefined points of time may increase the degree of efficiency of the RF radiation.

[0043] In connection with the drain opening, it shall be noted that providing a drain opening as such is substantially innocuous with regard to an escape of RF radiation through the drain opening, provided that the drain opening is substantially smaller than the wavelength of the RF radiation. In particular, the wavelength of the RF radiation is in the order of meters, meaning that it is well possible to design the drain opening sufficiently small that an escape of RF radiation through the drain opening can be inhibited. Ordinary drain opening sizes for draining water or liquids, as known from kitchen sinks, may for example be used. Respective sized may be in the order of several centimeters up to, for example 10 cm. By suitably designing the drain opening, containment and shielding of RF radiation by the cavity walls may be ensured.

[0044] In case that the appliance comprises, in addition to a RF source, also a microwave source, for example for heating/cooking the defrosted or thawed object, in particular a food object, providing the closure or lid for the drain opening may be advantageous. By closing the closure or lid in a microwave-based operation, the microwave radiation may be prevented from leaking through the drain opening. By this, sufficient containment and shielding may be obtained also for microwave radiation. Closures and lids may be advantageous also for other cooking methods, such as steam cooking, convection heating, whereby escape of heat from the cavity thorough the drain opening may be inhibited.

[0045] As already indicated, a microwave source may be provided in addition to the RF source for use in a heating or cooking process, wherein heating/cooking

based on microwaves as such is well known in the art.

[0046] The heating or cooking process may be carried out subsequent to a defrosting and thawing cycle. In particular, defrosting or thawing and subsequent heating, in particular cooking, may be carried out in a sequential order and in an automated manner. The heating or cooking process by using microwave energy may be monitored and controlled by a corresponding control unit based on microwave and/or RF radiation supplied to the cavity and reflected back from and/or absorbed within the cavity.

[0047] In embodiments, supplying aqueous steam to the cavity may comprise supplying at least one of cold aqueous steam and hot aqueous steam to the cavity. Cold aqueous steam may for example be related to steam below or equal to 100 °C, such as room temperature, temperatures above 60 °C, in particular above 80 °C, or at or around about 100 °C. Hot aqueous steam may be related to steam above 100 °C. In particular aqueous steam over 100°C, in particular overheated aqueous steam, may be supplied to the cavity in connection with defrosting and/or tempering.

[0048] In connection with supplying steam to the cavity, the appliance may comprise a steam generator and supply means, comprising for example inlet openings, in particular inlet orifices or nozzles, for supplying the steam directly to the cavity. The cavity as such, in particular the drain opening, may be configured to be steam-tight, for example by providing corresponding steam-tight cavity walls and by implementing the drain opening with a steam tight closure or lid. Appropriate gaskets and the like may be provided to keep the aqueous steam within the cavity to avoid undesired leakage. In embodiments, a steam-inlet may be implemented in association, in particular integrally, with the drain opening, which may reduce the number of openings to be produced in the cavity walls.

[0049] For collecting condensed aqueous steam drained to the outside of the cavity, the appliance may comprise a collection reservoir, which may for example be provided below the cavity. The reservoir may be communicatively coupled via the drain opening with the cavity interior. The reservoir may be implemented as a closed space, for example as a closed sump, in particular such that leakage of condensed aqueous steam collected in the reservoir, leakage of aqueous steam, and leakage of RF radiation and others may be inhibited. The reservoir may be connected to a drainage duct and/or pump for draining collected liquids from the reservoir.

[0050] In all, it can be seen that the method according to the invention and a corresponding appliance, are suitable for efficiently defrosting, in particular thawing, an object, in particular a food object. In particular, advantages for efficient and comparatively fast defrosting and thawing can be obtained by simultaneously supplying RF energy and aqueous steam to the cavity. Further, based on analysing the reflected RF radiation and/or the RF power absorbed, it is possible to automatically control and/or conduct a defrosting or thawing process. As such,

a corresponding analysis may provide information that enables tuning and optimizing the RF radiation for use in the defrosting or thawing cycle. Further, such an analysis may be used for detecting an endpoint of defrosting or thawing, which in turn may be used for stopping the defrosting or thawing. Subsequent to such a detection, further process steps may be, in particular semi-automatically or automatically, started or initiated, such as tempering the object by continued supply of aqueous steam, or starting a subsequent heating or cooking cycle or process for heating or cooking the object, based for example on inductive heating, radiant heating, steam heating, convection heating, microwave heating and others.

[0051] Yet further, the suggested method and appliance enable an efficient use of RF energy for thawing, in particular by tuning the RF radiation and/or by draining surplus condensed aqueous steam (and other liquids) from the cavity via a drain.

[0052] According to further embodiments, a method of operating a cooking appliance to defrost and/or cook an object, in particular a food object, placed within a treatment cavity of the appliance.

[0053] In the sense of the underlying invention, the term defrosting shall comprise thawing. Further, the term cooking shall be understood as comprising heating an object that is already defrosted, or subsequent to defrosting the object. In this connection, the expression "defrosting and cooking" shall comprise defrosting the frozen object followed by cooking, or in other words heating the defrosted or thawed object.

[0054] Accordingly, a corresponding method may comprise the following steps:

i) defrosting, if required, the object based on a method according to a method as herein described under any of the embodiments in connection with the invention, and subsequently, after stopping the defrosting, based on a corresponding cooking instruction,

ii) heating the defrosted object with a heating unit of the appliance, wherein the heating unit is configured for heating the object within the cavity based on at least one of: convection heating, steam heating, microwave heating, inductive heating and radiant heating.

[0055] The heating in step ii) may be conducted according to a given cooking scheme or procedure.

[0056] In addition, prior to carrying out step i) the method may include a step of determining whether the object in the cavity is, at least in part, in a frozen state. If a frozen state is determined, the method may proceed with step i). If it is determined that the object is not frozen, i.e. that there is no need to defrost, the method may proceed with step ii). Step i) may for example be carried out, if an explicit instruction of a user or a defrosting and cooking

program exists.

[0057] The defrosting according to step i) and/or the heating according to step ii) may, at least in part, be carried out automatically, or at least semi-automatically. For example, controlling the defrosting and/or heating in an automated manner, a corresponding control unit of the appliance may analyse and detect one or more cooking parameters such as, but not limited to: temperature, size, volume, distribution, condition and/or the cooking state of the object in the cavity, as well as the (defrosting, heating, or cooking) time and others. At least some of the parameters may be determined based on supplying electromagnetic radiation to the cavity accommodating the object, and analysing at least one of reflected and absorbed electromagnetic radiation. This means, the cavity comprising the object may be scanned using the electromagnetic radiation, and the scanning result may be analysed for detecting or deriving respective parameters or states, to be used or suitable for controlling the defrosting and/or cooking.

[0058] The electromagnetic radiation may comprise radiation of at least one of the radio, the microwave, the infrared and the visible electromagnetic spectrum. For example, and as described above, RF radiation, that is provided for conducting the defrosting cycle, may be analysed for determining an end point of defrosting. Microwave radiation may be used and reflected and/or absorbed radiation may be analysed for determining a cooking state and/or shape of the object, for example. Infrared radiation may be used for temperature measurements. Electromagnetic radiation in the visible spectrum may be used for detecting the shape, location, surface texture etc. of the object, for example. A corresponding appliance may comprise corresponding sources for supplying the electromagnetic radiation to the cavity, and may further comprise appropriate sensors and analysing units for detecting and analysing reflected and/or absorbed radiation. The radiation source/s, the sensor/s and analysing unit/s may be implemented as a kind of scanner for scanning the cavity interior, and for determining one or more cooking parameters as mentioned beforehand, for example.

[0059] A control unit may be provided for controlling the defrosting and/or cooking based on the analysis.

[0060] The defrosting according to step i) may be carried out if required, meaning, for example, that the defrosting may be carried out responsive to an explicit instruction received via a user interface of the appliance, and/or an instruction as part of an operating program to be carried out by the appliance, for example.

[0061] Further, the defrosting according to step i) may be carried out based on a determination of the appliance, e.g. a corresponding control unit, that the object is in a frozen state. A determination that the object is in a frozen state may for example be made based on a temperature measurement carried out by the appliance, and/or based on an RF sweep as described in further details below and above.

[0062] Hence, if an explicit instruction exists, or if a corresponding determination is made by the appliance that the object is frozen, the method may involve operating the appliance in a defrosting mode according to step i), which involves a method as described in connection with embodiments given further above.

[0063] The heating according to step ii) may be carried out if a corresponding cooking instruction is present or available, for example for the controller of the appliance. As such, the instruction may be received via a user interface, for example. The cooking instruction may also be part of a cooking program to be carried out by the appliance.

[0064] Hence, operating the appliance according to the suggested method may involve a defrosting operational mode, a cooking mode, and a combined defrosting and cooking mode comprising a defrosting step or phase followed by a cooking step or phase carried out subsequently to each other. In particular, the suggested method enables, as required or selected by a user, defrosting only, cooking only, and defrosting and cooking. As described herein, carrying out the method, and operating the appliance accordingly, may be automated or at least semi-automated in that the frozen state and the defrosted state of an object may be automatically determined. The method therefore may in particular be directed to defrosting and cooking a frozen object, in particular frozen food object, placed in the treatment cavity of the appliance.

[0065] In embodiments, the method may comprise the following steps:

a) receiving the object in the treatment cavity of the appliance;

b) performing at least one impedance sweep within a predetermined impedance sweep range and/or at least one RF sweep within a predetermined RF sweep range, wherein the predetermined RF sweep range is preferably centered about one or more ISM radio frequencies;

c) measuring the amount of RF energy or power that is supplied, via the impedance sweep and/or the radio frequency sweep, to the cavity, and that is reflected back from the cavity over the entire impedance sweep range and/or the entire RF sweep range;

d) based on the measuring, determining or selecting a RF and/or impedance value for which the radio frequency power supplied to the cavity is maximized while the radio frequency power reflected back is minimized;

e) supplying RF power to the cavity according to the determining or selecting; e.g. operating the RF source according to the determined RF and/or impedance value;

f) supplying aqueous steam to the cavity by activating a steam source, at least in part simultaneously to supplying the radio frequency power to the cavity;

g) repeating, at defined intervals of time, the steps b), c), and d);
wherein

f1) if it is determined in step d) that a maximum RF power absorbed is larger than a predetermined absorption threshold, proceeding with steps e) to g); and f2) if it is determined in step d) that the maximum RF power absorbed is equal to or less than the absorption threshold, the method comprises stopping the supply of RF radiation for defrosting the object to the cavity, and optionally stopping the supply of aqueous steam to the cavity; and

subsequently to step f2), based on a cooking instruction:

g) starting a cooking phase for cooking the object based on a cooking method comprising at least one of: convection heating, steam heating, microwave heating, inductive heating and radiant heating of the object.

[0066] As explained in detail above, the defrosting and cooking may be carried and controlled in an automated, at least however semi-automated, manner for example based on scanning the cavity with electromagnetic radiation. By this, an automated or semi-automated defrosting and cooking of an object, in particular food object, may be obtained, wherein the initial state of the object may be frozen.

[0067] The steps f1) and f2), may relate to step d) carried out for the first time, or they may relate to step d) carried out in repetition according to step g). In case that steps f1) and f2) are carried out already upon performing step d) for the first time, the method may be configured for detecting whether or not the object that has been inserted into the cavity is in a frozen or defrosted state. If, however, steps f1) and f2) are carried out only in the repetition(s) according to step g), the method carries out at least one defrosting cycle based on supplying RF radiation to the cavity.

[0068] The frozen or defrosted state of the object to be placed in the cavity may for example be determined automatically based on scanning the cavity with electromagnetic radiation, in particular radio frequency radiation. If the maximum power absorbed is equal to or lower than the absorption threshold the method may determine that the object is sufficiently defrosted, and the method may proceed with cooking according to step g). Otherwise one or more defrosting cycles may be carried out until it is determined that the object is sufficiently defrosted, e.g. by a determination that the maximum power absorbed is equal to or lower than the absorption threshold.

[0069] In embodiments, the appliance or method may involve monitoring the amount of RF radiation reflected by, and if the amount or ratio of reflected RF exceeds a threshold, the method or appliance may tune the frequency of the RF radiation of the impedance with a RF sweep and/or impedance sweep. If tuning the RF radiation such that the absorption is above the absorption threshold, as described further above, is not possible, the method or device may determine that the defrosting or thawing is sufficiently completed, and the defrosting and thawing cycle may be stopped.

[0070] As indicated, in embodiments the method may comprise a step of determining whether the object is in a frozen state and subsequent to such a detection, carrying out the defrosting according to step i) described above.

[0071] Further, the method may, in embodiments, comprise a step of determining that the object is in a defrosted state and subsequently, based on the cooking instruction, carrying out the heating according to step ii).

[0072] In embodiments, the method may further comprise at least one of the following steps:

- draining condensed aqueous steam from the cavity by opening a drain provided in the bottom of the cavity, in particular after predefined time intervals during defrosting according to step i);
- after step i) and before step ii), continuing supplying steam to the cavity for a predetermined period of time, a predicted period of time, and/or based on a measured temperature of the object.

[0073] Continuing supplying steam to the cavity may be carried out for tempering the object after defrosting based on the simultaneous supply of RF radiation and aqueous steam. The predetermined period of time, the predicted period of time, and/or the measured temperature of the object may be provided and obtained as described further above. Further, the draining of the condensed aqueous steam may be carried out as described further above.

[0074] In embodiments, an appliance, in particular a household appliance, for defrosting and/or cooking a food object, in particular in an automated manner, or at least in a semi-automated manner is provided. The appliance comprises:

- a cavity, in particular treatment cavity, for receiving the object;
- a RF source for supplying RF radiation to the cavity for capacitive radio frequency dielectric heating of the object;
- a steam source for supplying steam to the cavity; and
- a control unit coupled at least to the RF source and steam source and configured for controlling the steam source and RF source in accordance with a method according to at least one embodiment according to the invention as described herein.

[0075] The appliance may further comprise one or more heating units for heating, in particular cooking, the object, for example one of a convection heating, steam heating, microwave heating, inductive heating and radiant heating unit. The control unit may further be configured for carrying out, in an automated or semi-automated manner, a cooking process based on using one or more of the heating units.

[0076] The cavity may comprise cavity walls defining an inner space for accommodating the object, and a door for closing the inner space defined by the walls. The cavity may be designed according to appliances known in the art, e.g. according to a muffle of an oven. Further, the cavity, in particular the cavity walls and the door may be designed to prevent undesired leakage of radiation and steam supplied to the cavity during operation according to a method as described herein in connection with the invention.

[0077] In embodiments, the appliance may further comprise a drain unit for draining condensed aqueous steam, as well as other liquids, from the cavity. Draining condensed aqueous steam accumulating during a defrosting cycle as described herein may be carried out as discussed further above and further below. Further, the drain unit may be configured as described in further detail herein.

[0078] In particular, the drain unit may comprise a drain opening, preferably provided in a bottom side of the cavity, and wherein the control unit may be configured for opening, during a defrosting and/or cooking cycle, the drain opening for draining condensed aqueous steam, and also other liquids, from the cavity. The drain and drain opening may be configured and dimensioned such that at least electromagnetic radiation in the RF range can be prevented from leaking out of the cavity. As mentioned, the drain and drain opening may be associated with a cover or lid for opening and closing the drain opening.

[0079] The appliance may comprise a reservoir or sump, which may be communicatively coupled to the drain, in particular the drain opening. By this, condensed aqueous steam and other liquids may be drained via the drain, in particular drain opening, from the cavity interior. The reservoir may be designed as a substantially closed vessel communicatively coupled to the drain, wherein the vessel may be constructed with regard to dimensions and materials such that unwanted leakage of electromagnetic radiation, e.g. in the radiofrequency range, or in the microwave range in case the appliance includes a microwave heating unit.

[0080] In an alternative, the drain as such may be implemented as a reservoir or sump, and the appliance may comprise one or more drain pipes for draining liquids from the drain.

[0081] Liquids collected in the reservoir or sump may be removed via a draining system comprising, for example, one or more drain pipes, and optionally a drain pump for actively withdrawing liquids from the drain, in particular the reservoir or sump.

[0082] In embodiments, the control unit of the appliance may be further configured for automatically detecting an end of a defrosting phase or cycle based on a determination that a maximum absorbed RF power, i.e. a maximum RF power absorbed, within a given RF sweep range or within a given impedance sweep range is below a predefined absorption threshold.

[0083] In particular, the control unit may be configured for carrying out a RF sweep by supplying RF radiation to the cavity whilst varying the frequency of the RF radiation with time. By detecting and analysing the RF energy supplied to the cavity and the RF energy reflected back from the cavity over time, it is possible to identify the RF frequency value that is associated with a maximum energy absorption, i.e. a maximum RF energy or power absorbed. The RF source may subsequently be tuned to the identified RF value associated with maximum RF power absorbed, for emitting RF radiation to the cavity, for example for defrosting.

[0084] The RF frequency sweep may be carried out at power levels lower than the power level used for defrosting, in particular to prevent possible damages in non-resonant conditions, i.e. involving comparatively high RF reflection rates.

[0085] For detecting reflected RF radiation, the appliance may comprise a RF sensor for detecting the reflected RF radiation. For carrying out a RF sweep, the frequency of the RF radiation emitted by the RF source is changed or varied with time to scan, i.e. sweep, a desired frequency band, centered for example around one of the RF identified above, e.g. located in the ISM band. The control unit then analyses the reflected RF radiation signals to determine a particular RF frequency value at which the reflection is minimal, i.e. at which the absorption is maximal. This particular RF frequency value may be considered as corresponding to the resonance frequency of the load (i.e. the object in the cavity).

[0086] For carrying out an impedance sweep, the impedance of the RF source is varied with time while RF radiation of a fixed frequency value is supplied to the cavity. At the same, and similar to the RF sweep, the RF energy supplied to the cavity and the RF energy reflected back from the cavity over time is detected or measured, and based on the detection or measurement a particular impedance value may be determined for which a maximum RF energy absorption prevails. Having determined the particular impedance value, the impedance of RF source may be tuned or adjusted to the particular impedance value, in particular meaning that the RF source impedance is tuned such that the selected frequency value becomes the resonance frequency, where maximum power or energy absorption may be obtained. Having tuned the RF source, the RF radiation can be emitted to the cavity for defrosting, for example.

[0087] The described principle of performing a RF frequency sweep and/or impedance sweep may be applied analogously for tuning a microwave source in case that appliance comprises, for heating or cooking the object,

a corresponding tunable microwave source for heating/cooking the object.

[0088] The RF frequency sweep and/or impedance sweep may be used, as has been described above, to determine a frozen or defrosted state of the object. For this, the maximum energy or power absorbed can be further analysed, and for example compared with the absorption threshold to determine whether the object is (still) frozen or is already defrosted. For example, a situation in which the maximum absorbed RF power or energy determined within the RF frequency sweep range or the impedance sweep range is equal to or smaller than the absorption threshold may be indicative of a defrosted state, in particular defrosted condition, in which proceeding further with irradiating the object with RF radiation may or might have no or substantially no further defrosting or thawing effect due to low RF absorption. Further, stopping defrosting or thawing in case that the maximum absorbed RF power or energy is equal to or lower than the absorption threshold, may be advantageous with regard to avoiding possible adverse impacts on the RF source due to a comparatively high ratio of reflected RF radiation, and/or with regard to energy efficiency.

[0089] Further, a situation in which the maximum absorbed RF power or energy determined within the RF sweep range or the impedance sweep range is larger than the absorption threshold may be indicative of a state in which the object is still frozen at least to a certain extent. For the reason that the maximum absorbed RF power or energy in this situation is comparatively "high", the defrosting based on supplying RF radiation may be continued, in particular with adequate energy efficiency whilst avoiding possible adverse impacts of low RF absorption on the RF source.

[0090] The absorption threshold may for example be selected such that adverse effects on the RF source due to a high ratio of reflected RF radiation may be at least greatly avoided and/or such that the energy efficiency of defrosting or thawing lies within an acceptable and technically reasonable limits.

[0091] As an example, the absorption threshold may be 15 % to 25 %, in particular about 20 %, relative to the power supplied.

[0092] In embodiments, the appliance comprises a temperature sensing unit for sensing, determining and/or predicting a temperature value of the object, wherein the controller is configured to continue, based on the temperature value, supplying steam to the cavity after stopping the supply of RF radiation. Via continued supply of aqueous steam, the object may, for example, be subjected to a tempering process, in particular before starting a cooking process after defrosting.

[0093] The temperature sensing unit may for example be implemented as a temperature probe, in particular a contact thermometer, an infrared thermometer, and/or may be configured to determine or predict the temperature of the object based on reflected or absorbed RF energy or power determined from a frequency sweep or

impedance sweep, or other electromagnetic radiation.

[0094] In embodiments, a computer-program product is provided, comprising instructions, which, when executed by a computer, cause the computer to carry out the steps of a method according to any embodiment described herein in connection with the invention. The term computer shall be understood broadly as a device or machine that can be instructed to carry out arithmetic or logical operations. In particular, a computer in this connection shall comprise a controller or control unit of an appliance, such as a household appliance, suitable for controlling, at least in part, the operation or at least one or more operational modes of the appliance.

[0095] The computer-program product may for example relate to a storage device storing respective instructions. The instructions may be loaded, for example from a local or remote data source, into the memory of the computer for carrying out the underlying method. The computer, in particular controller or control unit, may be installed or integrated in the appliance, or may, at least in part and with regard to the appliance, be implemented as a remote device. By providing a corresponding computer-program product, a device equipped with all the relevant parts for carrying out a defrosting procedure according to the embodiments described in connection with the invention may be set up, configured or activated for carrying out a defrosting procedure as described by uploading and/or installing the computer-program product, i.e. respective instructions, to/on the controller or control unit communicatively coupled with the appliance for controlling at least some functions of the appliance.

[0096] The advantages and advantageous effects described and mentioned in connection with the suggested method/s apply mutatis mutandis also for the appliance and computer-program product.

[0097] Exemplary embodiments and aspects of the underlying invention will now be described in connection with the annexed figures, in which:

FIG. 1 shows a schematic and exemplary representation of an appliance suitable for defrosting and cooking an object;

FIG. 2 shows a schematic wiring and ducting diagram for the appliance;

FIG. 3 shows an exemplary process flow for a method for thawing an object;

FIG. 3 shows an exemplary process flow for thawing and cooling an object;

FIG. 4 shows an exemplary process flow for tuning the RF value or the impedance value of the RF source;

FIG. 5 shows operational steps according to an operation using an absorption threshold;

- FIG. 6 shows an additional heating or cooking step after defrosting or thawing;
- FIG. 7 shows an illustrative plot of RF radiation absorption versus frequency; and
- FIG. 8 shows an exemplary plot of the ratio of maximum RF power absorbed per total RF power supplied as a function of the temperature T of the object.

[0098] Throughout the figures, the same reference signs are used for elements or components that equal or equal in function or scope.

[0099] FIG. 1 shows a schematic and exemplary representation of an appliance 1 suitable for defrosting and cooking an object in accordance with a method according to the invention. The components of the appliance are shown and depicted at least in so far as necessary for understanding the underlying invention.

[0100] The appliance 1 may be a baking oven, comprising heating elements for cooking or baking, such as for example microwave heating elements, radiant heating elements, steam heating elements etc. as mentioned further above.

[0101] The appliance 1 comprises a support structure with an outer housing 2, and a user interface 3 with control elements for controlling the appliance 1.

[0102] The appliance 1 further comprises a cavity 4, which is configured for accommodating an object, in particular a food object (not explicitly shown in FIG. 1).

[0103] The appliance 1 further comprises a door (not shown) associated with the front opening of the cavity 4, and configured for closing the cavity 4, and enabling access to the cavity interior in the opened state. Such cavity and door configurations are known in the art.

[0104] The appliance 1 further comprises a radio frequency (RF) source 5 that is connected, for example with corresponding conductor plates 6 forming "antennas" for supplying RF radiation to the cavity 2, in particular to an object placed within the cavity 2.

[0105] The appliance 1 further comprises a steam generator 7 for generating aqueous steam. A steam output of the steam generator 7 is communicatively coupled with a cavity inlet opening 8 provided in or at a cavity wall such that the cavity interior, in particular an object placed within the cavity, may be impinged with and exposed to steam generated by the steam generator 7. An appropriate ducting (not shown) between the steam generator 7 and the cavity inlet opening 8 may be provided.

[0106] The appliance 1 further comprises, at a bottom wall of the cavity 4, a drain opening 9 that is part of a drain provided in connection with the cavity 4 and configured for draining condensed aqueous steam and other liquids from the cavity 4. As exemplarily shown in FIG. 1, the bottom wall may comprise inclined sections for gravity-based guidance of condensed steam or liquid towards the drain opening 9. The drain opening 9 may com-

prise a closure or lid (not shown) via which the drain opening 9 can be opened and closed. A corresponding drive unit may be provided for driving the closure or lid between the opened and closed state.

[0107] The appliance 1 further comprises one or more control units 10, communicatively interconnected with the user interface 3, in particular control units thereof, the RF source 5, the steam generator 7, and, if provided for, the drive unit for opening and closing the closure or lid. The one or more control units 10 are configured to control the appliance 1, in particular the identified components, at least in the extent of a method described herein in connection any embodiments of the invention.

[0108] FIG. 2 shows a schematic wiring and ducting diagram for the electric and electronic components of the appliance 1 described above. The electric and electronic components, i.e. the RF source 5, the steam generator 7 and the user interface 3 (and others), may be interconnected with the control unit 10, for example via a bus 11, and/or other suitable, e.g. separate, communication and control lines. The RF source 5 is connected via lines 12 to the conductor plates 6. The steam generator 7, specifically a steam outlet opening thereof, is connected via a ducting, schematically shown and depicted by reference sign 13, to the cavity inlet opening 8 to be able to feed or supply aqueous steam generated by the steam generator 7 via the cavity inlet opening 8 into the cavity 4. The user interface 3, including for example also one or more control and display elements, may also be interconnected via the bus 11 with the control unit 10. It shall be noted that other interconnections may be contemplated within the framework of the invention.

[0109] FIG. 3 shows an exemplary process flow for a method for defrosting or thawing an object, such as a food object having solid, liquid, and/or pasty consistence, according to an operational mode of the appliance 1. As a note, encircled alphabetic characters in the figures are provided to define links between different embodiments.

[0110] Such a method may comprise a step 301 in which the object to be defrosted or thawed is impinged with RF radiation, in particular RF power of a selected frequency or frequency range to thereby cause heating of the object via capacitive RF dielectric heating. The RF radiation may be supplied to the cavity by operating the RF source 5 as exemplarily shown in FIG. 1 and 2. To this end, the RF source 5, including for example a RF amplifier, may supply alternating electromagnetic energy to the conductor plates 6, in turn generating an alternating RF electromagnetic field in and near the space between the conductor plates 6. This alternating RF electromagnetic field may act on polarizable or polar molecules, e.g. water molecules, parts thereof or ions, included in the object, via dielectric forces, thereby raising their average kinetic energy and thereby the temperature of the object. This means that the object is heated via capacitive dielectric heating based on RF radiation.

[0111] As a note, the RF source 5 may for example be based on triode technology or any other technology for

RF radiation generation. Such techniques are well known in the art.

[0112] Further, such a method may comprise a step 302 in which, at least temporarily during the capacitive RF heating, aqueous steam is supplied to the cavity 4. The aqueous steam may be generated by the steam generator 7 and supplied via one or more cavity inlet openings 8 as exemplarily shown in FIG. 1. The steam is, at least in sections during the defrosting or thawing, applied simultaneously with the RF radiation.

[0113] The aqueous steam supplied to the cavity 4 has the effect that heat, in particular latent heat, of the steam may be transferred to the frozen object, thereby contributing to heating, in particular defrosting or thawing the object in the region of the object's surface. Due to the comparatively large wavelength of the RF radiation contemplated in accordance with the invention, which is in the order of meters, the RF radiation has a comparatively high penetration depth. For this reason, RF radiation is absorbed in deep surface layers, in particular in the inner volume, of the object, meaning that the defrosting or thawing process is not primarily limited to the outer layers of the frozen object. For the reason that the steam defrosts or thaws the outer layers of the object, the radio frequency radiation absorption in the at least partially defrosted or thawed regions decreases, thereby increasing absorption and defrosting in deeper layers.

[0114] In all, the use of steam helps to homogenize the RF absorption coefficient of the object, in particular a food object, especially in the outer surface regions and, by this, to accelerate the defrosting or thawing process. In particular, the steam acts on the surface, and therefore, the surface and near-surface layers defrost or thaws first. For the reason that RF absorption is most efficient in the temperature range from -4°C to -2°C for example, the at least partially or fully defrosted or thawed layers absorb less RF energy, meaning that RF energy that is supplied to the cavity 4 is conveyed further inside the object and absorbed by the still frozen layers or sections.

[0115] As mentioned further above, the RF radiation may have a frequency of less than 300 MHz. In particular ISM frequencies of for example 6.78 MHz, 13.56 MHz, 27.12 MHz or 40.68 MHz may be used.

[0116] For the steam, both hot or cold humid air, aqueous steam at 100°C , or overheated aqueous steam may be used.

[0117] Accordingly, simultaneously applying the steam and the RF radiation is effective in speeding up the defrosting or thawing time. Further, by the combined use of steam and RF radiation, the object may be defrosted and thawed without generating overheated surface regions and without leaving inner still frozen sections.

[0118] In order to obtain most efficient defrosting and thawing the method may comprise steps for tuning the RF radiation or the impedance of the RF source 5 to the absorption resonance frequency of the object to maximize radio frequency absorption.

[0119] A flow diagram including corresponding method steps is shown in FIG. 4, which will be described below.

[0120] A corresponding tuning may be based on a RF sweep or impedance sweep over a given RF sweep range or impedance sweep range to find the particular radio frequency or impedance associated with a maximum RF absorption. In more details, the tuning steps may comprise:

- 10 - supplying 401 RF radiation within a predetermined RF sweep range and/or impedance sweep range to the cavity 4,
- measuring 402 the amount of RF energy supplied to and reflected back from the cavity over the RF sweep range and/or impedance sweep range;
- 15 - determining 403 a RF value and/or impedance value within the RF and/or impedance sweep range for which the RF power absorbed within the cavity 4 is maximized or for which the maximum RF power absorbed exceeds a predefined threshold value;
- 20 - applying 404 or setting the determined RF and/or impedance for value heating the object.

[0121] For measuring the RF radiation that is reflected back from the cavity 4, i.e. that is not absorbed within the cavity, the appliance 1 may comprise a suitable sensor unit (not shown). For evaluating and analysing the sensed reflection data, in particular in relation to the RF energy or power supplied to the cavity 4, the appliance 1 may comprise a controller configured for carrying out such evaluations and analyses. Such a controller may also be configured for determining the RF or impedance value according to step 403. Further, such a controller may instruct the radio frequency generator 7 to supply RF radiation in accordance with the determined RF or impedance value. Corresponding controllers and their function may be, at least in part, implemented with the control unit 10 exemplarily shown in FIG. 1.

[0122] The method steps 401 to 404 may be carried out before step 301, wherein after step 404, the method may proceed with step 301, which is indicated in FIG. 3 and 4 by an encircled "A".

[0123] It may be advantageous for obtaining efficient heating that the procedure of tuning or adapting the RF or impedance value to maximize the RF absorption is carried out repeatedly during the defrosting or thawing process. A repetition of tuning or adapting the RF or impedance value may be carried out after predetermined time intervals, for example. In particular, and as exemplarily depicted in FIG. 3 with the additional but optional step 501 (indicated by dashed lines), the controller or the control unit 10, for example, may check whether a predetermined time has lapsed since starting defrosting or thawing. If the determination is "no", the controller or control unit 10 may control the appliance to proceed further with defrosting or thawing according to steps 301 and 302 and simultaneously apply RF radiation and steam. If the determination is "yes", the controller or control unit

10, may stop the operations according to steps 301 and 302, and instruct the appliance 1 to carry out steps 401 to 404 (see encircled "B"), wherein thereafter, the method may proceed further with the operation according to steps 301 and 302 (see encircled "A").

[0124] By repeatedly tuning the RF source 5, a more efficient use of RF energy and better defrosting results may be obtained.

[0125] According to step 403, the method as suggested may involve determining whether the maximum RF power absorbed exceeds a predefined absorption threshold, which will be described in further detail below.

[0126] In case that a corresponding absorption threshold is used, the controller or the control unit 19, for example, may be configured to determine, for the RF sweep range or the impedance sweep range the maximum RF power absorbed, and to determine whether or not the determined maximum RF power absorbed is larger, or is equal or less the absorption threshold. Such an optional operation is indicated in FIG. 4 and 5, wherein the interconnections and branching between the method steps are indicated by dashed dotted lines. FIG. 5 shows additional (and optional) steps according to the operational variant using the absorption threshold.

[0127] If such an absorption threshold is used, the method according to FIG. 4 may branch off after step 403, and carry out step 601 (see FIG. 5). Accordingly, the controller or control unit 10, for example, may determine, after having determined the maximum RF power absorbed, whether the maximum RF power absorbed exceeds, i.e. is larger than, the absorption threshold, or is equal or lower than the absorption threshold.

[0128] If it is determined that the maximum RF power absorbed is larger than the absorption threshold ("yes" condition in FIG. 5), which is at least indicative of the possibility to continue RF-based defrosting under acceptable and sufficient absorption conditions, the method may proceed with defrosting according to steps 301 and 302, which is indicated by the encircled "A" in FIG. 5.

[0129] If it is determined that the maximum RF power absorbed is equal to or lower than the absorption threshold ("no" condition in FIG. 5), which is at least indicative that continuing RF-based defrosting is hardly or not possible any more under acceptable, reasonable and/or sufficient absorption conditions, the method may at least stop supplying the RF radiation for dielectric heating. This in particular means, that defrosting or thawing under use of the RF radiation is stopped.

[0130] The absorption threshold may be determined through experimentation, for example, and may, in embodiments, be specifically selected according to the type, structure and consistency of the object, provided, for example, the appliance 1 is configured to provide object-specific operation modes and/or is configured to determine respective object characteristics, e.g. in an automated manner and/or via instructions from a user interface in response to a corresponding user input. The absorption threshold may for example be set such that RF-

based defrosting or thawing is only continued or started if at least 20% of the RF energy or power supplied to the cavity is absorbed, e.g. if the maximum RF power absorbed is larger than 20% of the total RF power supplied.

[0131] After stopping the supply of RF radiation, the method may involve continuing supplying of steam to the cavity for a predetermined time interval for tempering the object, for example.

[0132] Further, the method may involve one or more steps of draining condensed steam or other liquids from the cavity 4 via the drain opening 9. Accumulated condensed steam or other liquids may absorb significant amounts of the RF radiation supplied to the cavity and thereby impair the defrosting or thawing for the object with regard to efficient use of energy.

[0133] Accordingly, the controller or the control unit 10, for example, may instruct from time to time, in particular after predefined intervals of defrosting or thawing using steam, a drive unit for opening the drain opening to drain accumulated liquid. Opening the drain opening 9, or, in alternatives, leaving the drain opening 9 open or providing a drain opening 9 without closure or lid, is innocuous with regard to RF leakage, due to the large wavelength of the RF radiation (in the order of meters) as compared to the size of the drain opening 9 designed for draining liquids (for example having a dimension in the order of several centimeters).

[0134] In particular, the drain opening 9 may be specifically designed in shape and size to avoid leakage of the RF radiation. By this draining the liquid may be carried out during defrosting without the need to stop supplying the RF radiation. Should leakage of RF radiation impose problems, the method may involve stopping the supply of RF radiation during the draining step.

[0135] After stopping the defrosting or thawing process, in particular after stopping the supply of RF radiation and the supply of steam to the cavity, the method may proceed with heating, in particular cooking the object. This is illustrated as an additional, but optional step 703 in FIG. 6, wherein branching off from stopping defrosting or thawing to heating or cooking is indicated by the encircled "D" in FIG. 5 and 6.

[0136] According to FIG. 6 a corresponding method may involve a step 701 of checking whether a heating or cooking instruction exists or is available. Such an instruction may for example be part of a combined defrosting or thawing and heating/cooking program for automatically or semi-automatically defrosting/thawing and heating/cooking an object, in particular food object. Hence the appliance 1 may be configured, e.g. comprise a corresponding program with instructions to be executed by the appliance 1 under the control of the control unit 10. By this, an operational mode for (semi-) automated defrosting/thawing and subsequent heating/cooking may be provided. The heating/cooking instruction may also be based on an explicit user instruction, for example received as a user input via the user interface 3.

[0137] If such a heating/cooking instruction does not

exist ("no" condition), the method may stop according to step 702, i.e. defrosting or thawing may be stopped, and accordingly the supply of RF radiation and steam may be stopped.

[0138] If such a cooking instruction exists ("yes" condition), the method may proceed with step 703 by heating the object, defrosted or thawed according to the preceding steps, with a heating unit of the appliance. The heating unit may be configured for heating the object within the cavity based on at least one of: convection heating, steam heating, microwave heating, inductive heating and radiant heating, preferably according to a given cooking scheme.

[0139] After finishing the heating/cooking step, the method may end at 704.

[0140] The method described in connection with FIG. 6 therefore enables to provide an appliance 1, in particular household appliance, that allows a user to carry out an automatic defrosting/thawing and heating/cooking procedure, thereby easing use of the appliance 1 for preparing food. Further, due to the efficient defrosting/thawing as suggested, energy-efficient and comparatively fast defrosting/thawing can be provided. Further, because the defrosting/thawing as suggested is able to defrost/thaw the whole object, in particular also parts located in the inner volume of the object, whilst overheated outer surface regions may be avoided, favourable results may be obtained, in particular with regard to food quality.

[0141] FIG. 7 shows an illustrative plot of RF radiation absorption (vertical axis in decibel db) versus frequency (horizontal axis in MHz). The frequency range may for example be related to an ISM frequency band, for example from 6.765 MHz to 6.795 MHz with a center frequency of 6.78 MHz (bandwidth 30 kHz), from 13.553 MHz to 13.567 MHz with a center frequency of 13.56 MHz (bandwidth 14 kHz), from 26.957 MHz to 27.283 MHz with a center frequency of 27.12 MHz (bandwidth 326 kHz), or from 40.66 MHz to 40.7 MHz with a center frequency of 40.68 MHz (bandwidth 40 kHz). Any other suitable frequency band may be used as well. For the intended illustrative purpose, it is not required to assign specific frequency values to the horizontal axis. The shown plot is illustrative for any frequency band, wherein the specific shape and peaks may vary.

[0142] For identifying a suitable RF value for defrosting or thawing according to step 403, the RF source 5 is operated, for example, at a comparatively low power value, wherein the frequency value of the radio frequency radiation emitted from the RF source 5 and supplied to the cavity 4 containing the object is swept over the given RF band, i.e. the frequency of the RF radiation emitted by the RF source 5 is gradually or in steps varied and supplied to the cavity 4. Concurrently with sweeping the RF value, the reflected RF energy or power is measured or detected. Based on the known RF energy or power of the RF radiation supplied to the cavity 4 and the measured or determined reflected RF energy or power, it is possible to determine the RF absorption or RF damping

of the RF radiation caused by the load comprising the object placed in the cavity 4.

[0143] The RF power absorbed may be expressed in decibel (db), which is well known in the art, wherein in the plot in FIG. 7, negative decibel values are indicative of RF damping or RF absorption, wherein the smaller absolute value of the negative decibel value is, the larger is the RF damping or RF absorption. In the given example two comparatively high peaks exist, one with an associated decibel value of about -10 db (K1) and one with an associated decibel value of about -22 db (K2). In the illustrative example, the RF frequency value F1 associated with the peak K1 provides an operational mode for the RF source 5 and for the given RF frequency band with a maximum RF power being absorbed. Accordingly, the defrosting or thawing process may be conducted by operating the RF source 5 with the RF value F1. For this, it is to be understood that the RF source 5 is tunable in that the output frequencies can be varied over a given frequency band as illustrated.

[0144] Such a RF sweep may be carried out repeatedly during defrosting or thawing to obtain maximum RF power yield and minimal defrosting or thawing time.

[0145] For carrying out an impedance sweep, the RF source 5 may be operated at a fixed RF value, e.g. with a center RF of the above-identified frequency bands, and the impedance of the RF source 5 may be varied over time, i.e. swept, within a given range of impedances. Again, the absorbed RF power may be monitored and the impedance corresponding to the maximum RF power absorbed may be set for operating the RF source 5. In order that the fixed RF of the RF source 5 ideally becomes the resonance frequency and thus provides maximal RF absorption, the impedance of the RF source 5, e.g. a radio frequency generator, shall be matched to the impedance of load. For this, a matching network on reactive lumped constants components may be provided for tuning, i.e. adapting, the impedance. Since the system has, at least approximately, a capacitive overall characteristic, an inductor may for example be used in the first instance to match the RF source's impedance to obtain maximal RF absorption. Other suitable methods for tuning and matching the impedance of the RF source 5 to the impedance of the load (the object placed in the cavity 4) may be used, inter alia depending on the characteristics of the RF generator and/or cavity used.

[0146] As explained above, in case that the maximum RF power absorbed is equal to or below a given absorption threshold, such as 20% of the total RF power supplied, the defrosting or thawing based on RF radiation may be stopped. Accordingly as long as the maximum RF power absorbed is larger than the RF absorption threshold, defrosting or thawing based on supplying RF radiation may be continued.

[0147] As mentioned further above, the suggested defrosting and thawing based on RF radiation enables automatically detecting the condition in which the object is sufficiently defrosted or thawed. For illustrative purposes,

FIG. 8 shows an exemplary plot of the ratio $P_{\max}/P$ of maximum RF power absorbed $P_{\max}$ per total RF power supplied P (vertical axis) as a function of the temperature T of the object (horizontal axis).

[0148] As may be inferred from FIG. 8, the ratio $P_{\max}/P$ decreases with increasing temperature T . When the temperature T of frozen food, for example, comes close to 0° , usually between -4°C and -2°C , depending inter alia on the food dielectric characteristics, the resonance curve becomes wide and the maximum RF power absorbed becomes much less compared to the initial one. At a certain temperature T , for example in the range of $[-4^\circ\text{C}; -2^\circ\text{C}]$, the maximum RF power absorbed $P_{\max}$ does any longer exceed a certain absorption threshold P_0 , for example 20 % of the total RF power supplied.

[0149] At this point, e.g. when the maximum RF power absorbed, corresponding to the resonance frequency does not any longer exceed the absorption threshold P_0 , the energy efficiency of the RF-based defrosting or thawing is comparatively poor, and the defrosting or thawing achieved by RF radiation can be considered as having reached the end, and the supply of RF radiation for defrosting or thawing may be stopped.

[0150] If desired, supplying aqueous steam to the cavity may be continued for a certain period of time after stopping supply of RF radiation, in particular for further tempering the object after defrosting or thawing based on RF radiation and, for example, before starting a cooking process.

[0151] In this connection it shall be noted that that a RF sweep or impedance sweep may be performed after draining condensed aqueous steam and other liquids. Therefore, each time a draining procedure is carried out, such a draining may be followed by a RF sweep or impedance sweep for determining a suitable RF and/or impedance value for tuning the RF source 5, where the RF radiation can be supplied with the resonance frequency of the load, i.e. the object placed in the cavity 4. In particular, each time a draining step is performed, a RF sweep or impedance sweep may be carried out.

[0152] Further draining steps may be carried out prior to starting the heating or cooking process, which have been described further above.

[0153] Yet further, if it is determined that the maximum RF power absorbed relative to the total RF power supplied is below the absorption threshold, a draining step followed by a RF sweep or impedance sweep may be carried out, for example to exclude that the reduction of RF power absorption is caused by advanced defrosting or thawing rather than excess of condensed aqueous steam or liquid. If, after the draining step, the maximum RF power absorbed relative to the total power supplied is still below the absorption threshold, it can be assumed that the object is sufficiently defrosted or thawed, and the supply of the RF radiation may be stopped. If, however, it is determined after the draining step that the maximum RF power absorbed relative to the total RF power supplied is above the absorption threshold, supplying RF

radiation may be continued.

[0154] As discussed above, a surplus or excess of condensed aqueous steam or liquid may be determined by using appropriate liquid sensors provided in connection with the drain.

[0155] As can be seen, and as has been shown, the suggested method and appliance is effective in obtaining improved defrosting, as well as assistance and support for a user to cook a defrosted object, in particular food object.

List of reference numerals

[0156]

1	appliance
2	outer housing
3	user interface
4	cavity
5	RF source
6	conductor plate
7	steam generator
8	cavity inlet opening
9	drain opening
10	control unit
11	bus
12	line
13	ducting
301 ff.	method steps
401 ff.	further method steps
501	further method step
601	further method step
701 ff.	further method steps
F	frequency value
K	peak
$P_{\max}$	maximum RF power absorbed
P	total RF power supplied
P_0	absorption threshold

Claims

1. A method of operating an appliance (1), in particular household appliance (1), for defrosting (301, 302), in particular thawing (301, 302), a frozen object, in particular a frozen food object, placed in a treatment cavity (4) of the appliance (1), the method comprising:

- a) heating (301) the frozen object via capacitive radio frequency dielectric heating by supplying radio frequency (RF) radiation of a selected frequency or frequency range to the cavity (4); and
- b) at least temporarily during the capacitive radio frequency heating, supplying (302) aqueous steam into the cavity.

2. The method according to claim 1, wherein the frequency of the RF radiation is smaller than 300 MHz, in particular the radio frequency lies in the range from 5 MHz to 50 MHz, in particular, wherein the radio frequency is selected to lie in a frequency band centered around one of the frequencies comprising 6.78 MHz, 13.56 MHz, 27.12 MHz, and 40.68 MHz.
3. The method according to any of the preceding claims, further comprising a step of performing (401) a radio frequency sweep and/or impedance sweep for the cavity (4), the radio frequency and/or impedance sweep comprising:
 - c) supplying (401) radio frequency radiation within a predetermined radio frequency sweep range and/or impedance sweep range to the cavity (4),
 - d) measuring (402) the amount of energy supplied to and reflected back from the cavity (4) over the frequency sweep range and/or impedance sweep range;
 - e) determining (403) a radio frequency and/or impedance value within the frequency and/or impedance sweep range for which the radio frequency power absorbed within the cavity (4) is maximized or for which the maximum radio frequency power absorbed ($P_{\max}$) exceeds a predefined absorption threshold (P_0);
 - f) applying (404) the determined radio frequency and/or impedance value for heating the object according to step a).
4. The method according to claim 3, comprising repeating the steps c) to e) at defined intervals during the defrosting, and carrying out step f) if it is determined (601) that the maximum power absorbed ($P_{\max}$) exceeds the predefined absorption threshold (P_0), and at least stopping (602) the supplying of the radio frequency radiation for dielectric heating if it is determined that the maximum power absorbed ($P_{\max}$) is below the predetermined absorption threshold (P_0).
5. The method according to any of claims 1 to 4, wherein the defrosting (301, 302)), at least the step of supplying (301) radio frequencies to the cavity (4), is stopped if a temperature of the object lies within a temperature range from -4°C to 0°C , in particular from -4°C to -2°C .
6. The method according to one of claims 4 or 5, wherein after stopping (602) the supply of the radio frequency radiation, the method comprises continuing with supplying aqueous steam to the cavity (4), for at least one of a predetermined and a predicted time interval.
7. The method according to at least one of claims 1 to 6, further comprising draining condensed aqueous steam from the cavity (4), preferably via a drain (9) provided in a bottom wall of the cavity (4).
8. The method according to any of claim 1 to 7, wherein the step of supplying (302) aqueous steam into the cavity (4) comprises supplying cold aqueous steam and/or hot aqueous steam, in particular aqueous steam at 100°C or overheated aqueous steam, into the cavity (4).
9. A method of operating a cooking appliance (1) to defrost and/or cook an object placed within a treatment cavity (4) of the appliance (1), the method comprising:
 - i) defrosting (301, 302), if required, the object based on an method according to at least one of claims 1 to 8; and subsequently, and, after stopping the defrosting (301, 302), based on a corresponding cooking instruction,
 - ii) heating the defrosted object with a heating unit of the appliance (1), wherein the heating unit is configured for heating the object within the cavity (4) based on at least one of: convection heating, steam heating, microwave heating, inductive heating and radiant heating, preferably according to a given cooking scheme.
10. The method according to claim 9, comprising determining whether the object is in a frozen state and subsequent to such a detection, carrying out the defrosting (301, 302) according to step i), and/or determining that the object is in a defrosted state and subsequently, based on the cooking instruction, carrying out the heating according to step ii).
11. The method of claim 9 or 10, comprising the following steps:
 - a) receiving the object in the treatment cavity of the appliance;
 - b) performing (401) at least one impedance sweep within a predetermined impedance sweep range and/or at least one radio frequency sweep (401) within a predetermined radio frequency sweep range, wherein the predetermined radio frequency sweep range is preferably centered about one or more ISM radio frequencies;
 - c) measuring (402) the amount of radio frequency energy that is supplied, via the impedance sweep and/or the radio frequency sweep, to the cavity (4) and that is reflected back from the cavity (4) over the entire impedance sweep range and/or the entire frequency sweep range;
 - d) based on the measuring, determining (403) a radio frequency and/or impedance value for

which the radio frequency power supplied to the cavity (4) is maximized while the radio frequency power reflected back is minimized;

e) supplying (301) radio frequency power to the cavity according to the determining;

f) supplying (302) aqueous steam to the cavity (4) by activating a steam source (7, 8) at least in part simultaneously to supplying (301) the radio frequency power to the cavity (4);

g) repeating, at defined intervals of time, the steps b), c), and d);

wherein

f1) if it is determined in step d) that a maximum power absorbed is larger than a predetermined absorption threshold, proceeding with steps e) to g); and

f2) if it is determined in step d) that the maximum power absorbed is equal to or less than the absorption threshold, the method comprises stopping (602) the supply of radio frequency for defrosting the object to the cavity (4), and optionally stopping the supply of aqueous steam to the cavity (4); and

subsequently to step f2), based on a cooking instruction:

g) starting (703) a cooking phase for cooking the object based on a cooking method comprising at least one of convection heating, steam heating, microwave heating, inductive heating and radiant heating of the object.

- 12.** The method according to any of claims 9 to 11, wherein the method comprises at least one of the following further steps:

- draining condensed aqueous steam from the cavity by opening a drain provided in the bottom of the cavity (4), in particular after predefined time intervals during defrosting (301, 302) according to step i);

- after step i) and before step ii), continuing supplying (302) steam to the cavity (4) for a predetermined period of time, a predicted period of time, and/or based on a measured temperature of the object.

- 13.** An appliance (1), in particular a household appliance (1), for defrosting (301, 302) and/or cooking (701, 703) a food object, in particular in an automated or semi-automated manner, comprising;

- a cavity (4) for receiving the object;

- a radio frequency source (5) for supplying radio frequency radiation to the cavity (4) for capacitive radio frequency dielectric heating of the object;

- a steam source (7, 8) for supplying steam to the cavity (4); and

- a control unit (10) coupled at least to the radio frequency source (5) and steam source (7, 8) and configured for controlling the steam source (7, 8) and radio frequency source (5) in accordance with a method according to at least one of claims 1 to 12.

- 14.** The appliance (1) according to claim 13, comprising a drain unit (9) for draining condensed aqueous steam from the cavity (4), wherein the drain unit (9) comprises a drain opening (9), preferably provided in a bottom side of the cavity (4), and wherein the control unit is configured for opening, during a defrosting (301, 302) and/or cooking cycle (701, 703), the drain opening (9) for draining condensed aqueous steam from the cavity (4) .

- 15.** The appliance (1) according to one of claims 13 and 14, wherein the control unit (10) is further configured for automatically detecting (601, 602) an end of a defrosting phase based on a determination that a maximum power absorbed ($P_{\max}$) within a given frequency or impedance sweep range is below a predefined absorption threshold (P_0), wherein the absorption threshold (P_0) preferably is 15 % to 25 %, in particular 20% relative to the power supplied (P).

- 16.** The appliance (1) according to at least one of claims 13 to 15, further comprising temperature sensing unit for sensing, determining and/or predicting a temperature value of the object, wherein the controller (10) is configured to continue, based on the temperature value, supplying aqueous steam to the cavity (4) after stopping (602) the supply of radio frequency radiation to the cavity (4).

- 17.** A Computer-program product comprising instructions which, when executed by a computer, cause the computer to carry out the steps of a method according to any of claims 1 to 12.

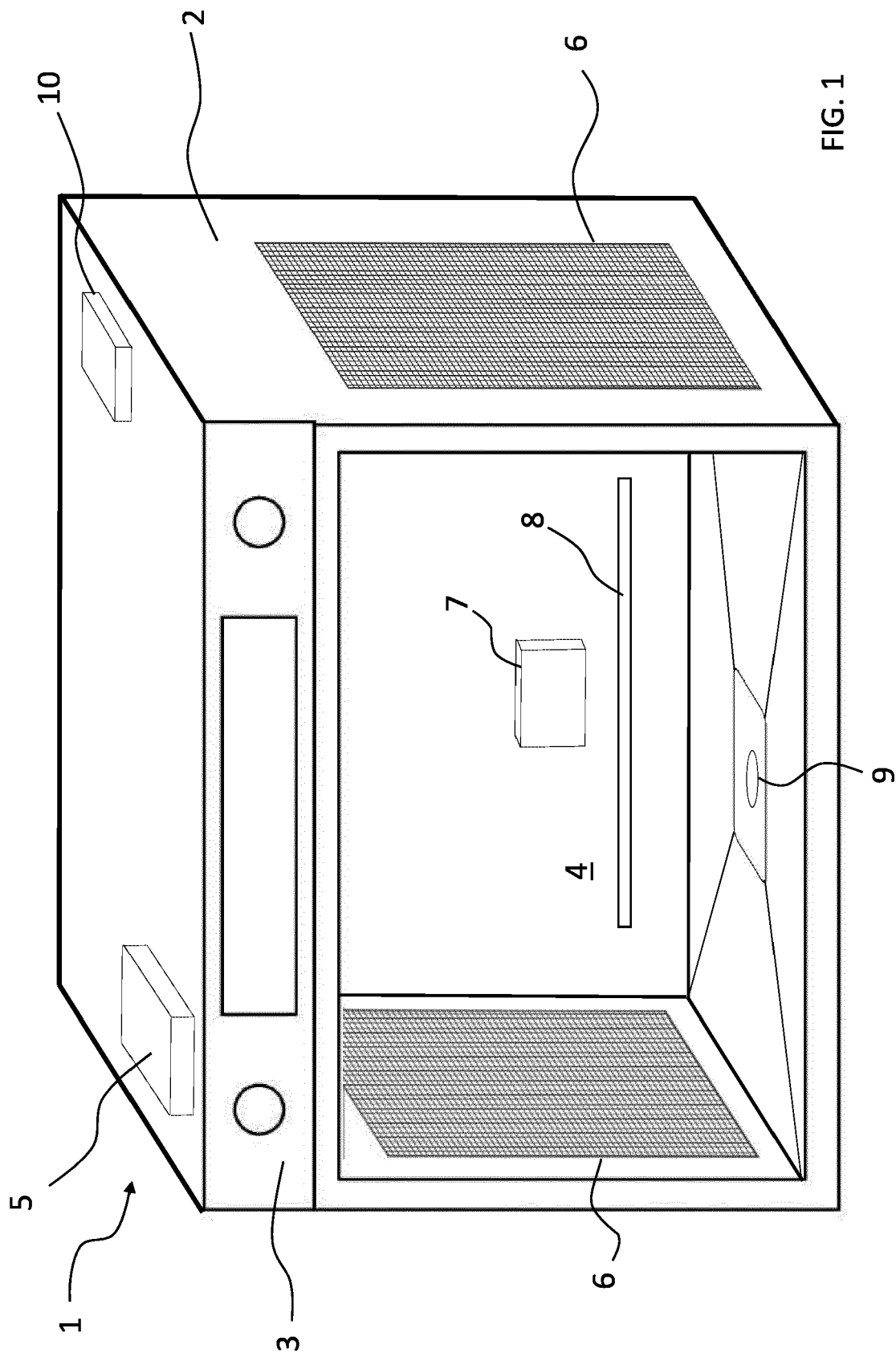


FIG. 1

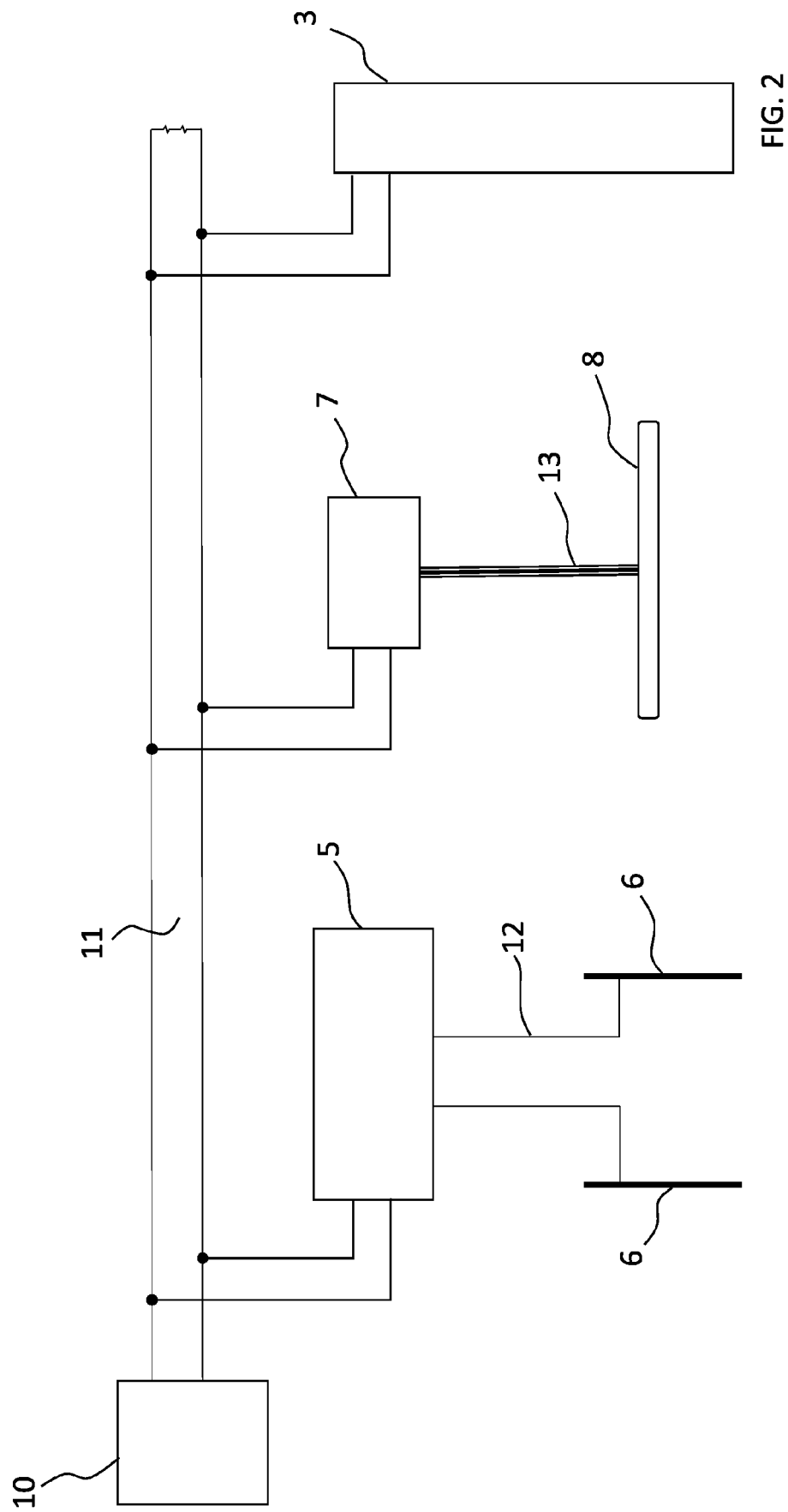


FIG. 2

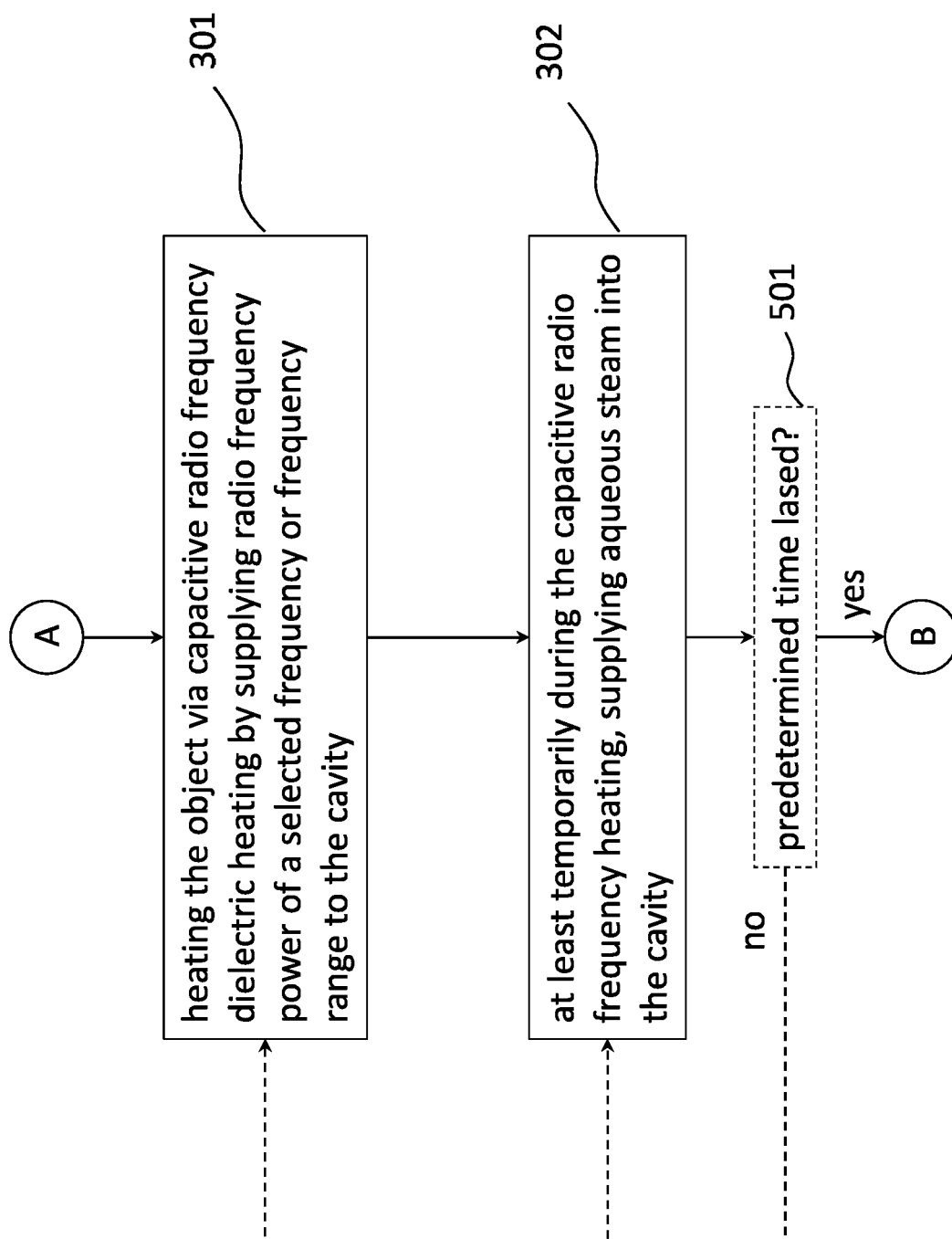


FIG. 3

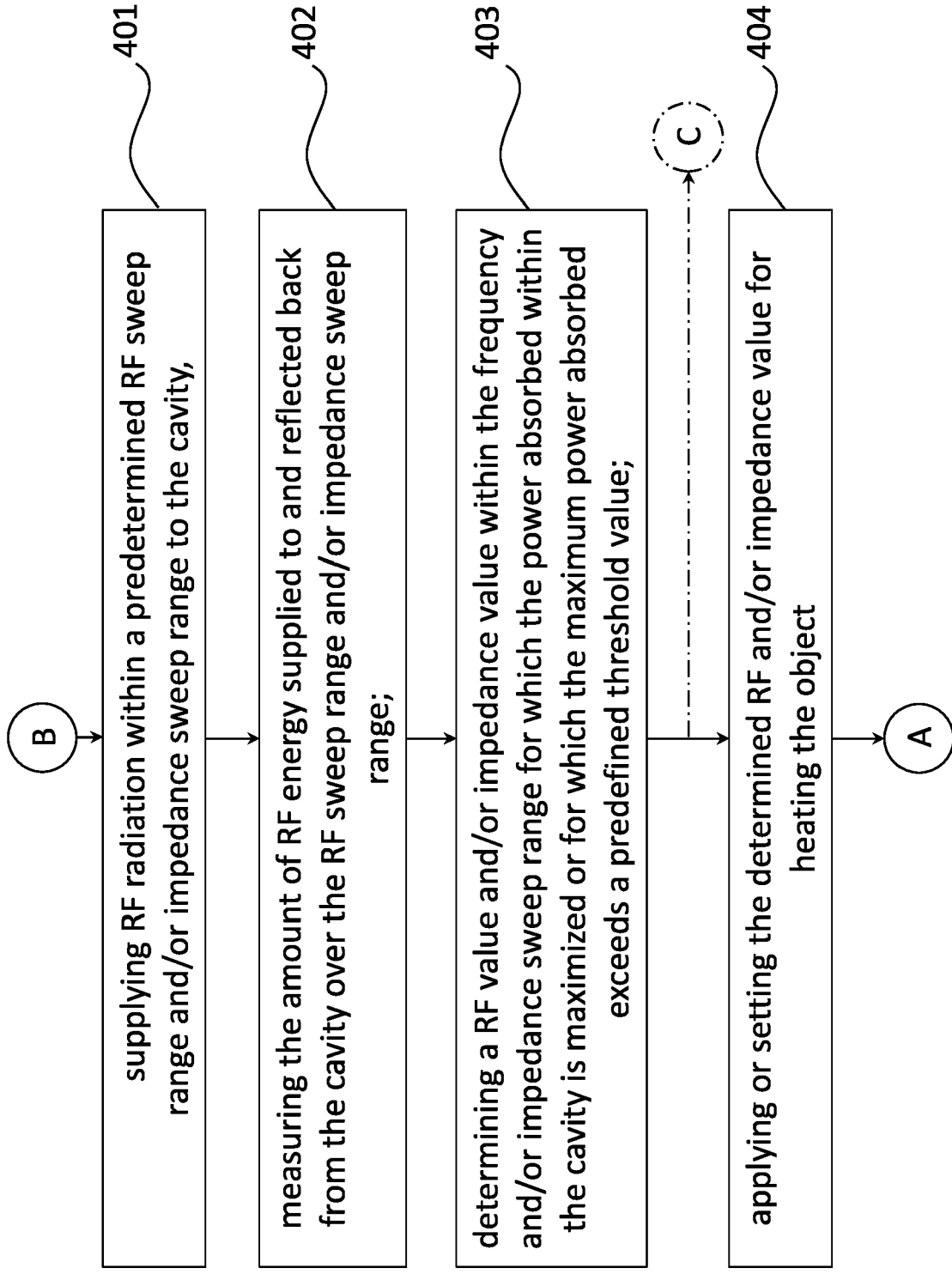


FIG. 4

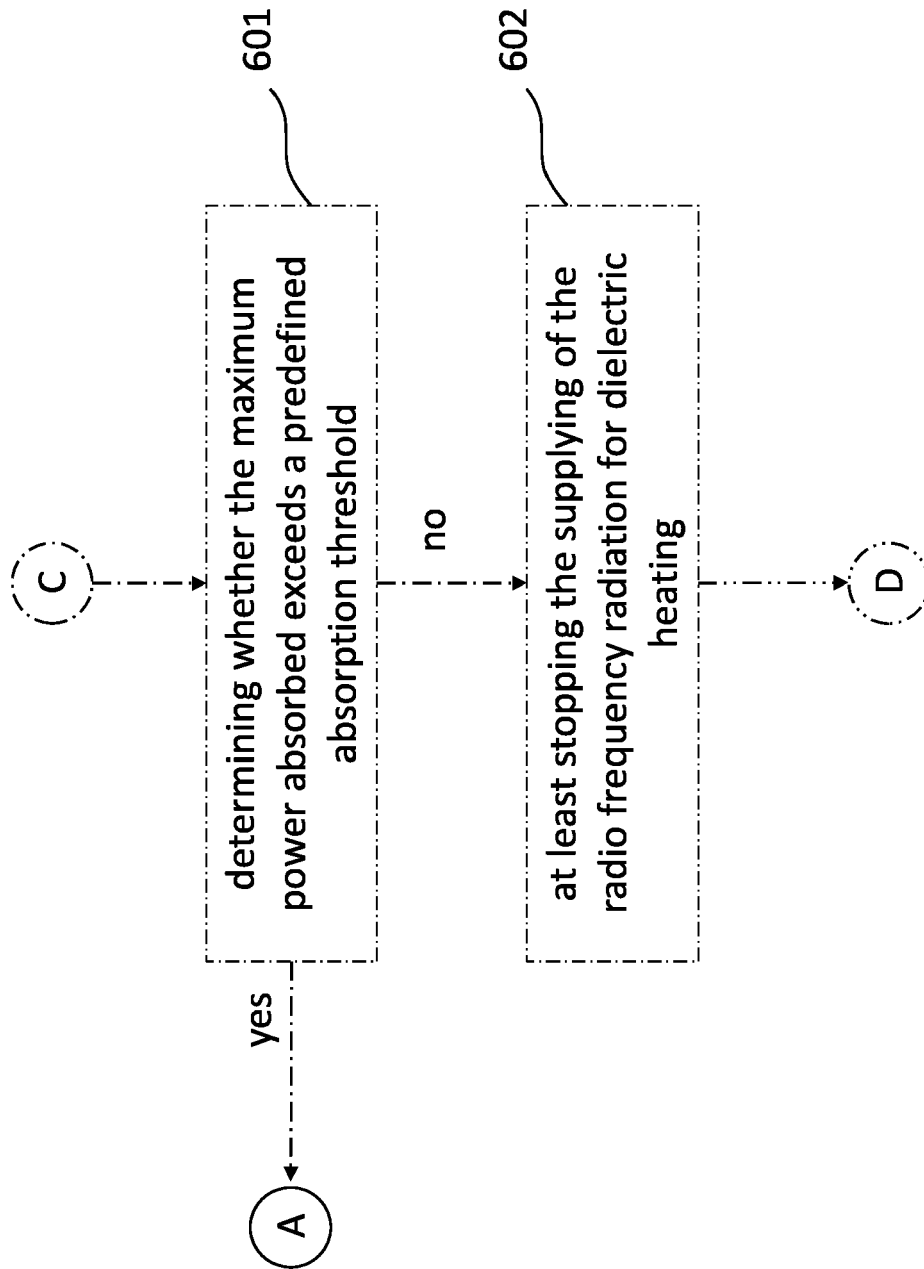


FIG. 5

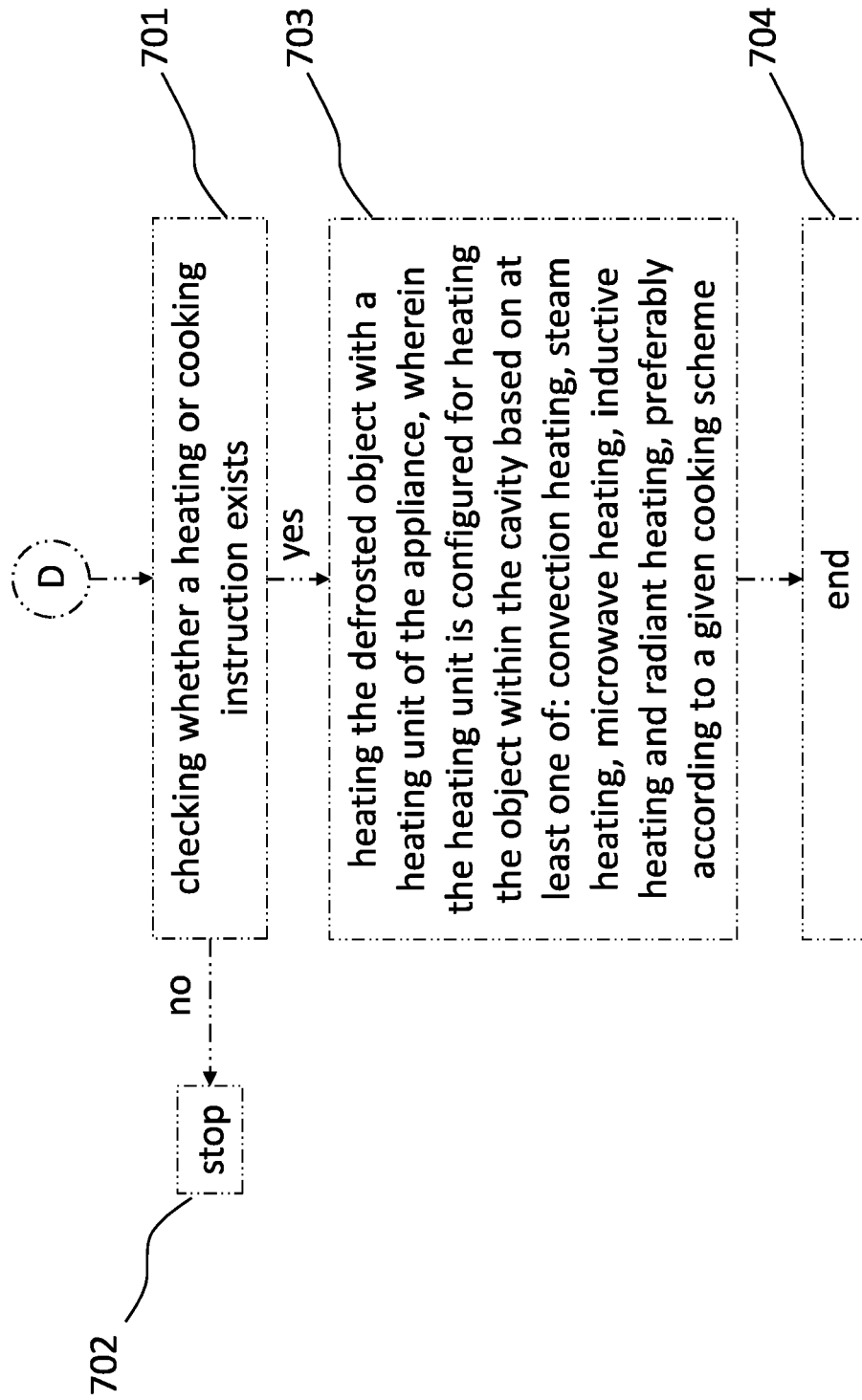


FIG. 6

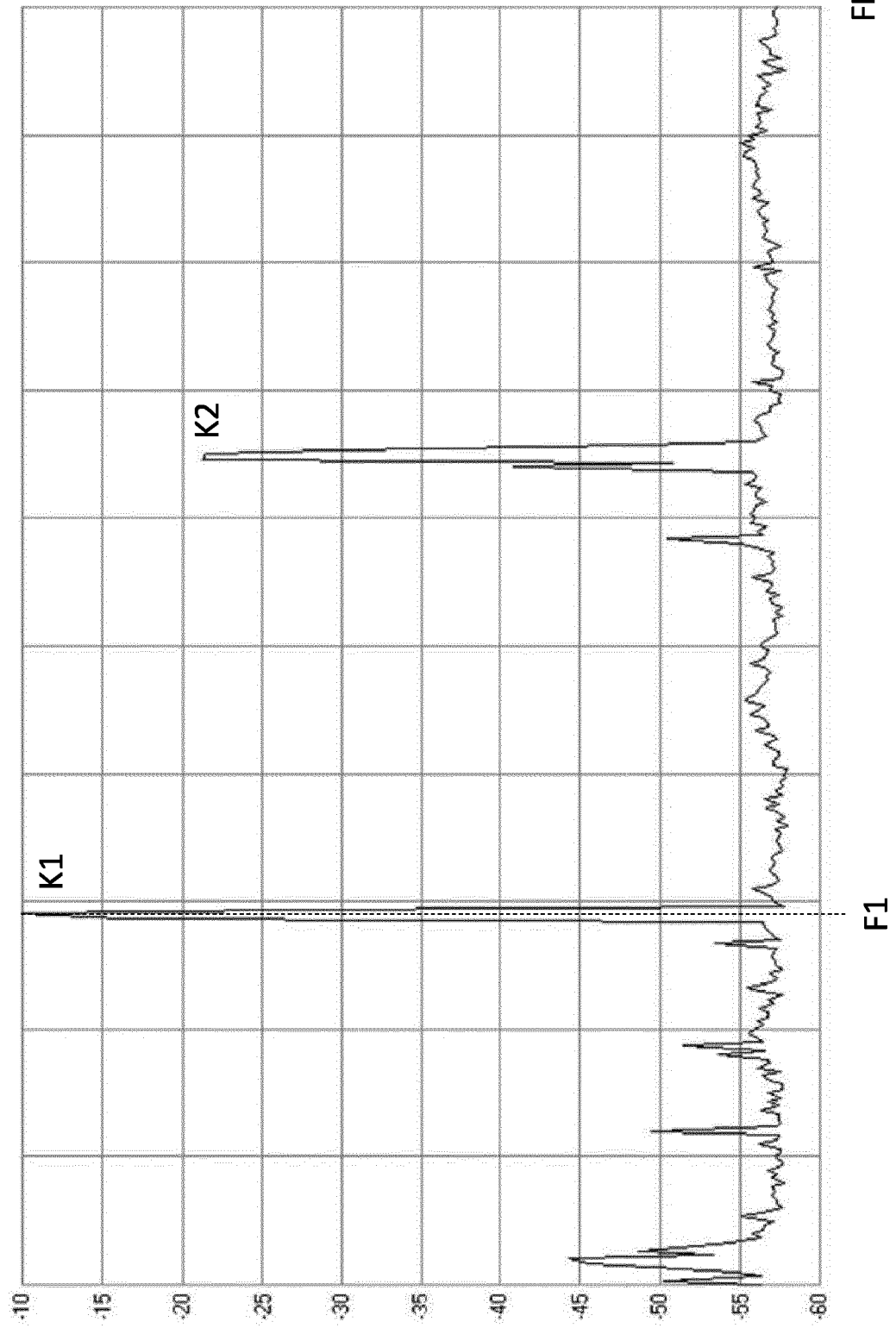


FIG. 7

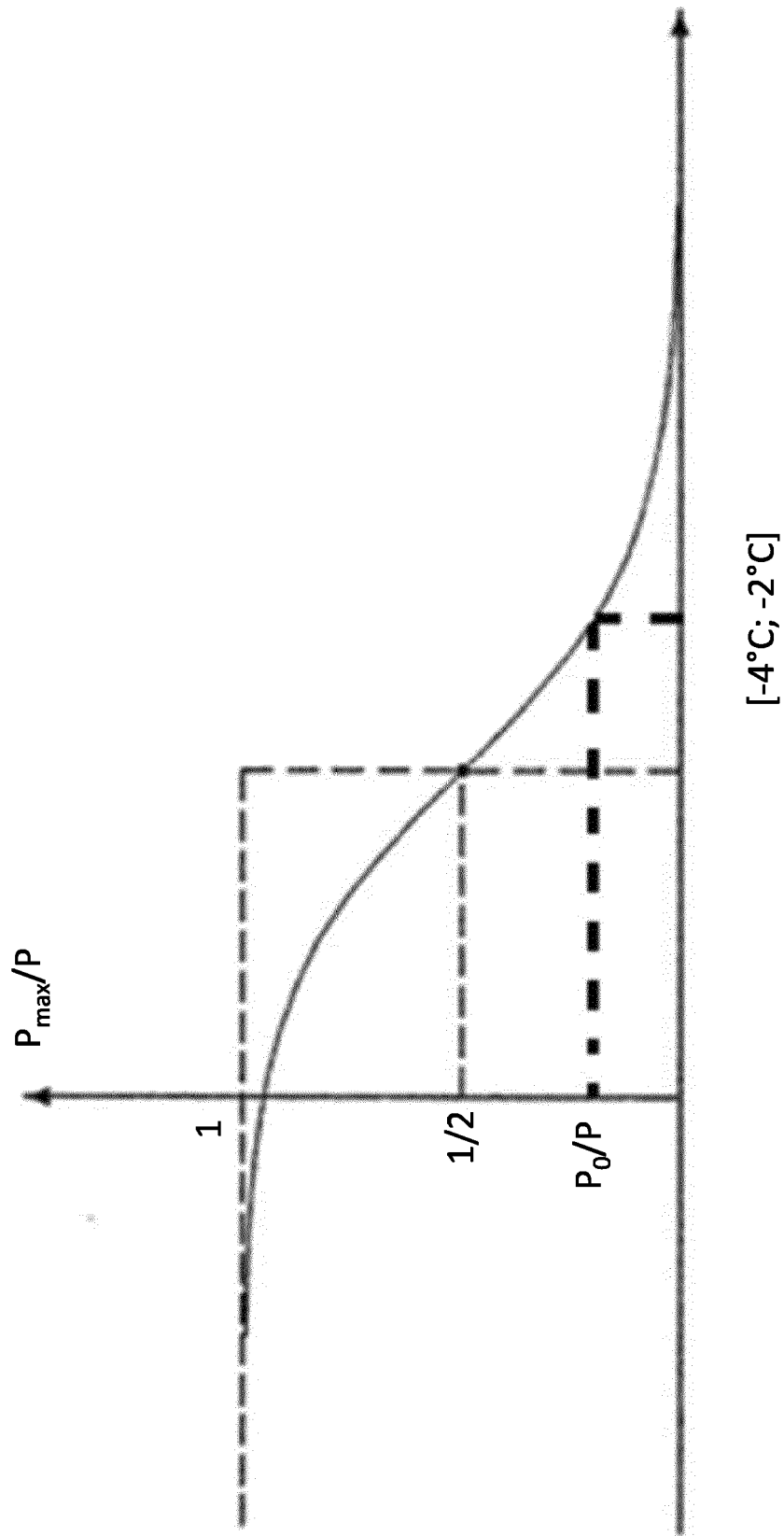


FIG. 8



EUROPEAN SEARCH REPORT

Application Number
EP 20 21 4409

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			H05B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 21 May 2021	Examiner Garcia, Jesus
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