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(54) **INDUCTION HEATING COOKER AND HEATING METHOD**

(57) The present invention relates to an induction heating cooker (1) and a heating method for the induction heating cooker (1). The induction heating cooker (1) comprises a heater (2) with an inner coil (3) and an outer coil (4) disposed concentrically in dual structure arranged to

apply magnetic energy for heating a vessel placed on a heating zone (Z), two power control circuits (5) for separately driving the inner coil (3) and the outer coil (4), and a processing means (6) for controlling the operation of the power control circuits (5).

Description**Technical Field**

5 **[0001]** The present invention relates to an induction heating cooker comprising a heater with concentric dual coils and a heating method for the induction heating cooker.

Background of the Invention

10 **[0002]** In the induction heating cookers, use of heaters with concentric dual induction coils are known in order to heat the vessels place on a heating zone. One of the critical points in providing an improved cooking experience is heating the heating zone with homogeneous heat distribution. Since size and electromagnetic characteristics of vessels being heated on the heating zone directly affect transmission of heat energy for heating, control of heating adapted per vessel is required for improved heating performance. At the same time, in order to prevent fluctuations in transmitted power and unwanted noise, the heating coils should be driven at a common frequency and constant phase difference.

15 **[0003]** In the state of the art, Japanese patent application no. JP2008117722A discloses an electromagnetic cooker wherein dual coils are controlled separately for uniform heating based on sensed temperature. Another prior art document, Japanese patent application no. JP2011222535A discloses an induction heating cooker wherein inner and outer coils of the cooker are separately controlled depending on the size of cooking utensil and temperature feedback. None of the cited documents discloses, however, an induction heating cooker and heating method ensuring uniform heating and smooth operation without using additional sensing components.

Aim

25 **[0004]** The aim of the present invention is to overcome the shortcomings of prior art by realization of an induction heating cooker and an automatic heating method for the induction heating cooker, wherein heating energy is transmitted to a cooking utensil uniformly and seamlessly, regardless of the type of the cooking vessel. Another purpose of the present invention is to provide an induction heating cooker and heating method that provides uniform heating at all desired power levels of the cooker. Accordingly, it is aimed to enhance cooking performance and customer satisfaction.

Brief Description of the Invention

30 **[0005]** The induction heating cooker and the heating method for the induction heating cooker in order to achieve the aims of the present invention are defined in independent claims 1 and 10, and in the dependent claims thereof.

35 **[0006]** The induction heating cooker comprises a heater with an inner coil and an outer coil disposed concentrically in dual structure, arranged to apply magnetic energy for heating a vessel placed on a heating zone, two power control circuits for separately driving the inner coil and the outer coil, and a processing means for controlling the operation of the power control circuits.

40 **[0007]** In a preferred embodiment of the invention, the processing means is configured to

- activate the power circuits, when a vessel is placed on the heating zone, to scan the coils and generate a data set comprising power of each coil at a plurality of operating frequencies and phase differences,
- check whether there is at least one common frequency for both coils,
- determine common minimum total power and common maximum total power of the coils,
- 45 - obtain set power level for the heating zone, set by a user of the induction heating cooker,
- check whether the sum of set power portion to minimum power ratios for each coil is less than 1,
- if the sum of set power portion to minimum power ratios is not less than 1, select, by referring to the data set, a common frequency and a phase difference such that ratio of outer coil power to inner coil power at said common frequency and phase difference is equal to a predetermined value providing substantially homogeneous heating at the heating zone,
- 50 - check whether the set power level is less than common maximum total power of the coils,
- if the set power level is not less than the common maximum total power, operate the coils at a partly-joint operating mode wherein, during a first part of the operating cycle both coils are energized, and during a remaining part of the cycle only one of the coils is energized at its maximum power,
- 55 - if the set power level is less than the common maximum total power, operate the coils at a partly-separate operating mode wherein the outer coil and the inner coil are energized such that the pulse driving the outer coil leads the pulse driving the inner coil by the selected phase difference and said pulses partly overlap.

[0008] As a result, inner and outer coils of the dual-coil structure are separately controlled to be driven at a frequency and phase difference selected in accordance with the characteristics of a cooking vessel placed on the heating zone such that the power transmitted to the inner and outer coils provide uniform heating.

[0009] In an embodiment, the processing means further configured to, if there is no common frequency for both coils, operate the coils at an alternating-mode wherein the outer coil and the inner coil are energized such that the pulse driving the inner coil leads the pulse driving the outer coil and said pulses do not overlap.

[0010] The processing means may be further configured to

- check whether the common minimum total power of the coils is less than a predetermined maximum power limit, and
- if the common minimum total power is not less than the predetermined maximum power limit, operate the coils at an alternating-mode wherein the outer coil and the inner coil are energized such that the pulse driving the inner coil leads the pulse driving the outer coil and said pulses do not overlap. In this way, it is ensured that the heating zone is not overheated, and the uniformity of heat distribution is maintained.

[0011] According to an embodiment, the processing means is further configured to, if the sum of set power portion to minimum power ratios for each coil is less than 1, operate the coils at a separate-mode wherein the outer coil and the inner coil are energized such that the pulse driving the inner coil leads the pulse driving the outer coil, said pulses do not overlap and both coils are off for a certain period during a driving cycle.

[0012] In some embodiments, the processing means is further configured to

- if a common frequency and a phase difference such that ratio of outer coil power to inner coil power at said common frequency and phase difference is equal to a predetermined value cannot be found, select different frequencies for the coils provided that the ratio of outer coil power to inner coil power still yields the predetermined value and the difference between those different frequencies is not more than a predetermined first threshold,
- check whether the frequency difference is less than a predetermined second threshold, and
- if the frequency difference is less than the predetermined second threshold, operate the coils at a joint-mode wherein the outer coil and the inner coil are energized simultaneously and continuously. By ignoring insignificant frequency difference, the processing means provides that the induction heating cooker is controlled and operates in a more stable manner, especially at high power levels.

[0013] According to an embodiment, the predetermined value indicating ratio of outer coil power to the inner coil power for obtaining uniform heating is between 1.3 and 1.8, and preferably 1.4.

[0014] The processing means may be further configured to scan the coils and generate a data set by scanning the coils separately. The processing means may be further configured to scan the coils and generate a data set by further scanning the coils jointly. Thus, the data set may comprise scanning results obtained by scanning the inner coil and the outer coil at different times, and results obtained by scanning the inner and outer coils simultaneously. The processing means may be configured to scan the coils for different phase differences, preferably by gradually incrementing/decrementing the applied phase difference at predetermined amounts, such as 30°.

[0015] The data set may comprise any data suitable for obtaining power values of inner and outer coils, including but not limited to voltage and current measurements of control circuit components such as IGBTs, on and off times of a respective coil within a cycle, and applied phase differences.

[0016] According to another aspect of the present invention, there is provided an automatic heating method for the induction heating cooker. The method comprises:

- activating the power circuits, when a vessel is placed on the heating zone, to scan the coils and generating a data set comprising power of each coil at a plurality of operating frequencies and phase differences,
- checking whether there is at least one common frequency for both coils,
- determining common minimum total power and common maximum total power of the coils,
- obtaining set power level for the heating zone, set by a user of the induction heating cooker,
- checking whether the sum of set power portion to minimum power ratios for each coil is less than 1,
- if the sum of set power portion to minimum power ratios for each coil is not less than 1, selecting, by referring to the data set, a common frequency and a phase difference such that ratio of outer coil power to inner coil power at said common frequency and phase difference is equal to a predetermined value providing substantially homogeneous heating at the heating zone,
- checking whether the set power level is less than common maximum total power of the coils,
- if the set power level is not less than the common maximum total power, operating the coils at a partly-joint operating mode wherein, during a first part of the operating cycle both coils are energized, and during a remaining part of the cycle only one of the coils is energized at its maximum power,

- if the set power level is less than the common maximum total power, operating the coils at a partly-separate operating mode wherein the outer coil and the inner coil are energized such that the pulse driving the outer coil leads the pulse driving the inner coil by the selected phase difference and said pulses partly overlap.

Brief Description of the Drawings

[0017] The induction heating cooker and the heating method realized to attain the aim of the present invention is illustrated in the attached figures, where:

Figure 1 is a schematic diagram of an induction heating cooker according to an embodiment of the invention,
 Figure 2 is a schematic view of the operating states of the coils in partly-joint operating mode according to an embodiment of the invention,
 Figure 3 is a schematic view of the operating states of the coils in partly-separate operating mode according to an embodiment of the invention,
 Figure 4 is a schematic view of the operating states of the coils in alternating operating mode according to an embodiment of the invention,
 Figure 5 is a schematic view of the operating states of the coils in separate operating mode according to an embodiment of the invention,
 Figure 6 is a flow diagram of the heating method according to an embodiment of the invention,
 Figure 7 is a flow diagram of a part of the heating method according to an embodiment of the invention.

List of Parts

[0018] The elements illustrated in the figures are numbered as follows:

1. Induction heating cooker
2. Heater
3. Inner coil
4. Outer coil
5. Control circuit
6. Processing means
- Z. Heating zone
- P3. Power of inner coil
- P4. Power of outer coil

Detailed Description of the Invention

[0019] The induction heating cooker (1) comprises a heater (2) with an inner coil (3) and an outer coil (4) disposed concentrically in dual structure arranged to apply magnetic energy for heating a vessel placed on a heating zone (Z), two power control circuits (5) for separately driving the inner coil (3) and the outer coil (4), and a processing means (6) for controlling the operation of the power control circuits (5) (Figure 1).

[0020] The processing means (6) is configured to carry out the following actions:

- Activating the power circuits (5), when a vessel is placed on the heating zone (Z), to scan the coils (3, 4) by operating the coils (3, 4) a range of different frequencies and phase differences and generate a data set. The data set comprises information indicating power of each coil (3, 4) at each one of a plurality of operating frequencies and phase differences,
- checking, by referring to the data set, whether there is at least one common frequency for both coils (3, 4),
- determining, from the scanning results (i.e. the data set), common minimum total power (P_{t_min}) and common maximum total power (P_{t_max}) of the coils (3, 4), and preferably minimum common frequency (f_{min}) and maximum common frequency (f_{max}),
- obtaining set power level (P_s) for the heating zone (Z), which is set by a user of the induction heating cooker (1),
- checking whether the sum of set power portion to minimum power ratios for each coil (3, 4) is less than 1,
- if the sum of set power portion to minimum power ratios for each coil (3, 4) is not less than 1, selecting, by referring to the data set, a common frequency and a phase difference such that ratio of outer coil power (P_4) to inner coil power (P_3) at said common frequency and phase difference is equal to a predetermined value (K) providing substantially homogeneous heating at the heating zone (Z),
- checking whether the set power level (P_s) is less than common maximum total power (P_{t_max}) of the coils (3, 4),

- if the set power level (P_s) is not less than the common maximum total power (P_{t_max}), operating the coils (3, 4) at a partly-joint operating mode (Figure 2) wherein, during a first part of the operating cycle both coils (3, 4) are energized, and during a remaining part of the cycle only one of the coils (3, 4), preferably the outer coil (4), is energized at its maximum power, and
- if the set power level (P_s) is less than the common maximum total power (P_{t_max}), operating the coils (3, 4) at a partly-separate operating mode (Figure 3) wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the outer coil (4) leads the pulse driving the inner coil (3) by the selected phase difference and said pulses partly overlap.

[0021] Common minimum total power (P_{t_min}) and common maximum total power (P_{t_max}) denote respectively the minimum and maximum total powers of the coils (3, 4) when they are operated at a common frequency.

[0022] Sum of set power portion to minimum power ratios for each coil (3, 4) can be expressed with the following formula:

$$\begin{aligned} & (\text{Set power portion of inner coil } (P_{s3}) / \text{minimum power of inner coil } (P_{3_min}) \\ & + (\text{Set power portion of outer coil } (P_{s4}) / \text{minimum power of outer coil } (P_{4_min})) \end{aligned}$$

[0023] In the formula, P_{s3} and P_{s4} are portions of set power (P_s) to be provided respectively by the inner coil (3) and the outer coil (4). Set power (P_s) is required partly from the inner coil (3) and partly from the outer coil (4) such that the predetermined ratio (K) between the outer coil power (P_4) and the inner coil power (P_3), hence between P_{s4} and P_{s3} is maintained.

[0024] When the desired power level indicated by the set power level (P_s) is more than the common maximum total power (P_{t_max}) of the coils (3, 4), the coils (3, 4) are operated at the partly-joint operating mode for delivering their maximum power while uniformly heating the heating zone (Z). In this operating mode, although the power delivered by the coils may not meet the desired power level, the predetermined value (K) of power ratio, for example 1.3, and therefore homogenous heating is nevertheless maintained.

[0025] On the other hand, when the common total power of the coils (3, 4) can deliver the desired power level (P_s), the coils (3, 4) are operated in the partly-separate operating mode, which is suitable for most relatively high levels of set power (P_s), such as 7-8 out of a level range of 1-10.

[0026] Accordingly, the induction heating cooker (1) of the present invention automatically determines heating characteristics of the coils (3, 4) depending on properties of a cooking vessel placed on the heating zone (Z), and controls the operation of the coils (3, 4) in accordance with said characteristics and in line with the power level set by a user of the induction heating cooker (1) to deliver uniform heating to the cooking vessel.

[0027] If there is no common frequency for both coils (3, 4), the coils (3, 4) are operated at an alternating-mode wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4) and said pulses do not overlap (Figure 4). The alternating-mode is applicable, thus, at all desired power levels regardless of the set power level (P_s).

[0028] In an embodiment, the processing means (6) may be further configured to operate the coils (3, 4) at an alternating-mode also when the common minimum total power (P_{t_min}) is not less than a predetermined maximum power limit, such as 3600W.

[0029] According to an embodiment, if the sum of set power portion to minimum power ratios for each coil (3, 4) is less than 1, the coils (3, 4) are operated at a separate-mode (Figure 5) wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4), said pulses do not overlap and both coils (3, 4) are off for a certain period during a cycle.

[0030] The automatic heating method for the induction heating cooker (1) comprises

- activating the power circuits (5), when a vessel is placed on the heating zone (Z), to scan the coils (3, 4) and generating a data set comprising power of each coil (3, 4) at a plurality of operating frequencies and phase differences (100),
- checking whether there is at least one common frequency for both coils (3, 4) (200),
- determining common minimum total power (P_{t_min}) and common maximum total power (P_{t_max}) of the coils (3, 4) (300),
- obtaining set power level (P_s) for the heating zone (Z), set by a user of the induction heating cooker (1) (400),
- checking whether the sum of set power portion to minimum power ratios for each coil (3, 4) is less than 1 (500),
- if the sum of set power portion to minimum power ratios for each coil (3, 4) is not less than 1, selecting, by referring to the data set, a common frequency and a phase difference such that ratio of outer coil power (P_4) to inner coil

power (P3) at said common frequency and phase difference is equal to a predetermined value (K) providing substantially homogeneous heating at the heating zone (Z) (600),

- checking whether the set power level (Ps) is less than common maximum total power (Pt_max) of the coils (3, 4) (700),
- if the set power level (Ps) is not less than the common maximum total power (Pt_max), operating the coils (3, 4) at a partly-joint operating mode (800) wherein, during a first part of the operating cycle both coils (3, 4) are energized, and during a remaining part of the cycle only one of the coils (3, 4) is energized at its maximum power
- if the set power level (Ps) is less than the common maximum total power (Pt_max), operating the coils (3, 4) at a partly-separate operating mode (900) wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the outer coil (4) leads the pulse driving the inner coil (3) by the selected phase difference and said pulses partly overlap. (Figure 6)

[0031] The method may further comprise, if there is no common frequency for both coils (3, 4), operating the coils (3, 4) at the alternating-mode (201).

[0032] The method may further comprise

- checking, preferably following step 300, whether the common minimum total power (Pt_min) of the coils (3, 4) is less than a predetermined maximum power limit (301), and
- if the common minimum total power (Pt_min) is not less than the predetermined maximum power limit, operating the coils (3, 4) at the alternating-mode (302). If the common minimum total power (Pt_min) is less than the predetermined maximum power limit, the method may proceed to step 400. (Figure 7)

[0033] The method may further comprise, if the sum of set power portion to minimum power ratios for each coil (3, 4) is less than 1, operating the coils (3, 4) at the separate-mode (501).

[0034] The induction heating cooker (1) and heating method of the present invention provides, for every level of operating power level, uniformly distributed heating of cooking utensils by automatically controlling the inner coil (3) and the outer coil (4) of the heater (2) by selecting operating frequency, phase difference, and an operating mode from a plurality of operating modes, depending on characteristics of the used cooking utensil and the set power level (Ps). As a result, a heating zone (Z) of the induction heating cooker (1) can be uniformly heated under different circumstances, without having to use temperature sensing means.

Claims

1. An induction heating cooker (1) **comprising** a heater (2) with an inner coil (3) and an outer coil (4) disposed concentrically in dual structure arranged to apply magnetic energy for heating a vessel placed on a heating zone (Z), two power control circuits (5) for separately driving the inner coil (3) and the outer coil (4), and a processing means (6) for controlling the operation of the power control circuits (5), **characterized in that** the processing means (6) is configured to:

- activate the power circuits (5), when a vessel is placed on the heating zone (Z), to scan the coils (3, 4) and generate a data set comprising power of each coil (3, 4) at a plurality of operating frequencies and phase differences,
- check whether there is at least one common frequency for both coils (3, 4),
- determine common minimum total power (Pt_min) and common maximum total power (Pt_max) of the coils (3, 4),
- obtain set power level (Ps) for the heating zone (Z), set by a user of the induction heating cooker (1),
- check whether the sum of set power portion to minimum power ratios for each coil (3, 4) is less than 1,
- if the sum of set power portion to minimum power ratios for each coil (3, 4) is not less than 1, select, by referring to the data set, a common frequency and a phase difference such that ratio of outer coil power (P4) to inner coil power (P3) at said common frequency and phase difference is equal to a predetermined value (K) providing substantially homogeneous heating at the heating zone (Z),
- check whether the set power level (Ps) is less than common maximum total power (Pt_max) of the coils (3, 4),
- if the set power level (Ps) is not less than the common maximum total power (Pt_max), operate the coils (3, 4) at a partly-joint operating mode wherein, during a first part of the operating cycle both coils (3, 4) are energized, and during a remaining part of the cycle only one of the coils (3, 4) is energized at its maximum power,
- if the set power level (Ps) is less than the common maximum total power (Pt_max), operate the coils (3, 4) at a partly-separate operating mode wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the outer coil (4) leads the pulse driving the inner coil (3) by the selected phase difference and

said pulses partly overlap.

2. The induction heating cooker (1) according to claim 1, wherein the processing means (6) is further configured to:

- if there is no common frequency for both coils (3, 4), operate the coils (3, 4) at an alternating-mode wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4) and said pulses do not overlap.

3. The induction heating cooker (1) according to claim 1 or 2, wherein the processing means (6) is further configured to:

- check whether the common minimum total power (P_{t_min}) of the coils (3, 4) is less than a predetermined maximum power limit, and

- if the common minimum total power (P_{t_min}) is not less than the predetermined maximum power limit, operate the coils (3, 4) at an alternating-mode wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4) and said pulses do not overlap.

4. The induction heating cooker (1) according to any one of the preceding claims, wherein the processing means (6) is further configured to:

- if the set power level (P_s) is less than the common minimum total power (P_{t_min}), operate the coils (3, 4) at a separate-mode wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4), said pulses do not overlap and both coils (3, 4) are off for a certain period during a driving cycle.

5. The induction heating cooker (1) according to any one of the preceding claims, wherein the predetermined value (K) is between 1.3 and 1.8.

6. The induction heating cooker (1) according to claim 5, wherein the predetermined value (K) is 1.4.

7. The induction heating cooker (1) according to any one of the preceding claims, wherein the processing means (6) is further configured to scan the coils (3, 4) and generate a data set by scanning the coils (3, 4).

8. The induction heating cooker (1) according to claim 7, wherein the processing means (6) is further configured to scan the coils (3, 4) and generate a data set by further scanning the coils (3, 4) jointly.

9. A heating method for an induction heating cooker (1) according to any one of the preceding claims, wherein the method comprises:

- activating the power circuits (5), when a vessel is placed on the heating zone (Z), to scan the coils (3, 4) and generating a data set comprising power of each coil (3, 4) at a plurality of operating frequencies and phase differences (100),

- checking whether there is at least one common frequency for both coils (3, 4) (200),

- determining common minimum total power (P_{t_min}) and common maximum total power (P_{t_max}) of the coils (3, 4) (300),

- obtaining set power level (P_s) for the heating zone (Z), set by a user of the induction heating cooker (1) (400),

- checking whether sum of set power portion to minimum power ratios for each coil (3, 4) is less than 1 (500),

- if the sum of set power portion to minimum power ratios for each coil (3, 4) is not less than 1, selecting, by referring to the data set, a common frequency and a phase difference such that ratio of outer coil power (P_4) to inner coil power (P_3) at said common frequency and phase difference is equal to a predetermined value (K) providing substantially homogeneous heating at the heating zone (Z) (600),

- checking whether the set power level (P_s) is less than common maximum total power (P_{t_max}) of the coils (3, 4) (700),

- if the set power level (P_s) is not less than the common maximum total power (P_{t_max}), operating the coils (3, 4) at a partly-joint operating mode (800) wherein, during a first part of the operating cycle both coils (3, 4) are energized, and during a remaining part of the cycle only one of the coils (3, 4) is energized at its maximum power,

- if the set power level (P_s) is less than the common maximum total power (P_{t_max}), operating the coils (3, 4) at a partly-separate operating mode (900) wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the outer coil (4) leads the pulse driving the inner coil (3) by the selected phase difference

and said pulses partly overlap.

10. The heating method according to claim 9, wherein the method further comprises:

- 5 - if there is no common frequency for both coils (3, 4), operating the coils (3, 4) at an alternating-mode (201) wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4) and said pulses do not overlap.

11. The heating method according to claim 9 or 10, wherein the method further comprises:

- 10 - checking whether the common minimum total power (P_{t_min}) of the coils (3, 4) is less than a predetermined maximum power limit (301), and
 - if the common minimum total power (P_{t_min}) is not less than the predetermined maximum power limit, operating the coils (3, 4) at an alternating-mode (302) wherein the outer coil (4) and the inner coil (3) are energized such
15 that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4) and said pulses do not overlap.

12. The heating method according to any one of claims 9 to 11, wherein the method further comprises:

- 20 - if the set power level (P_s) is less than the common minimum total power (P_{t_min}), operating the coils (3, 4) at a separate-mode (501) wherein the outer coil (4) and the inner coil (3) are energized such that the pulse driving the inner coil (3) leads the pulse driving the outer coil (4), said pulses do not overlap and both coils (3, 4) are off for a certain period during a driving cycle.

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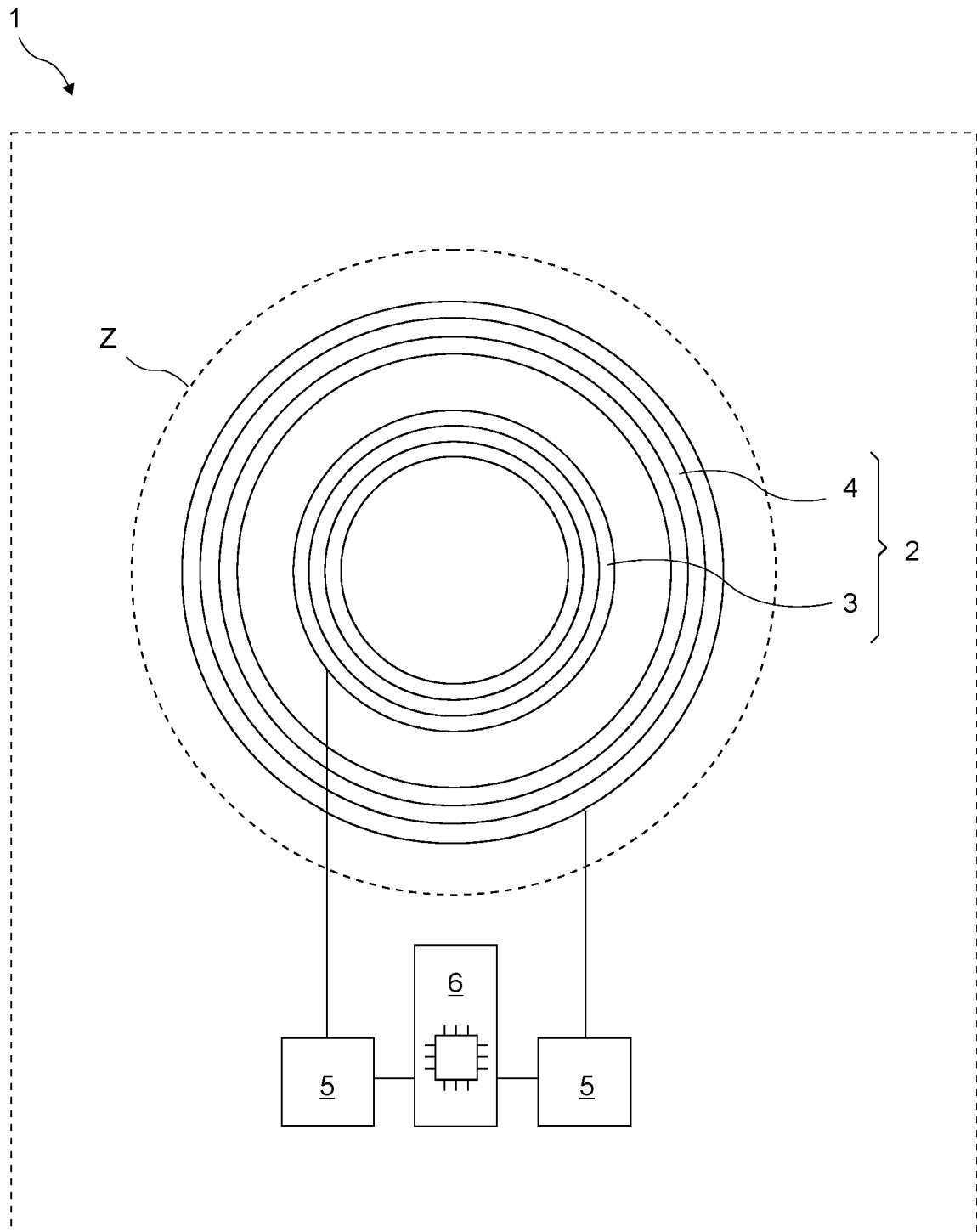


Figure 1

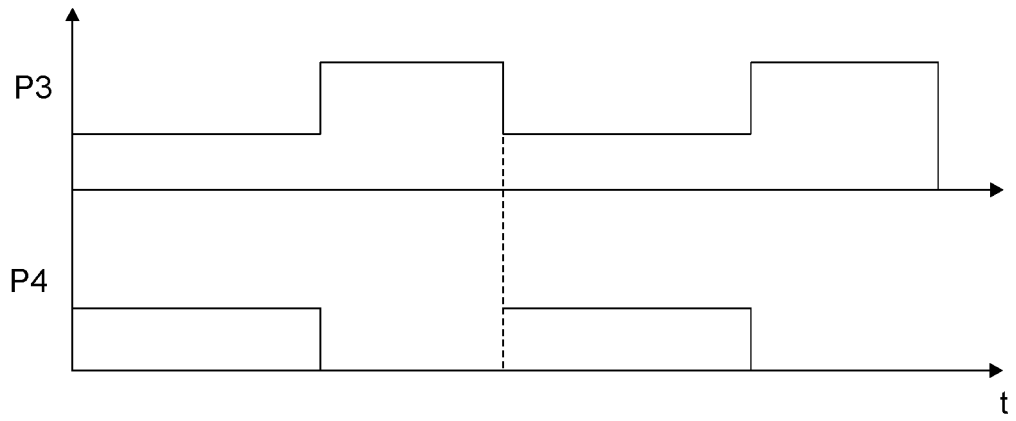


Figure 2

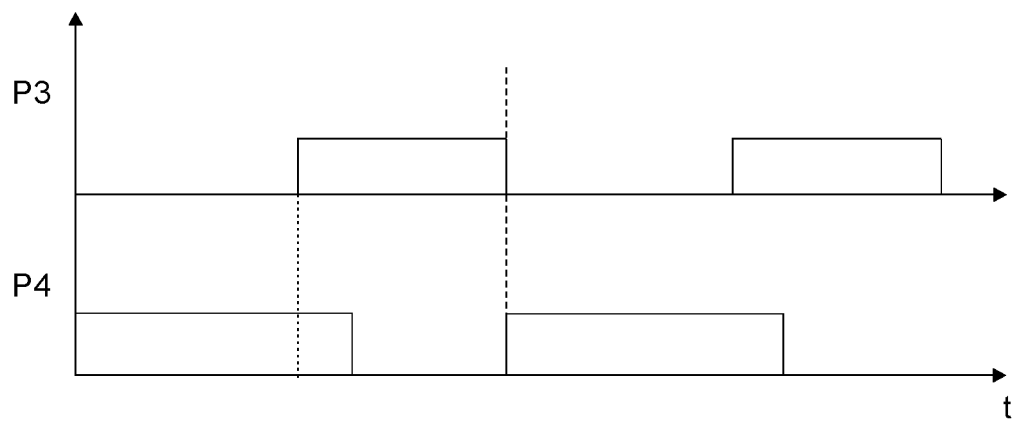


Figure 3

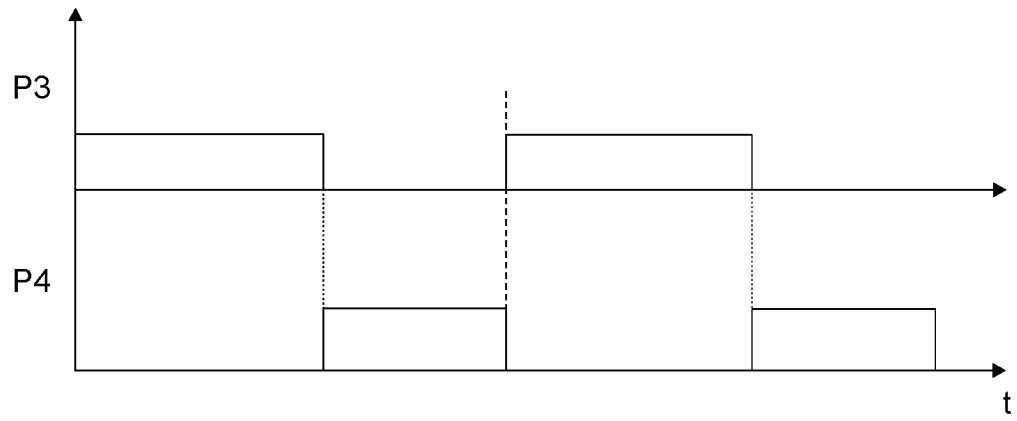


Figure 4

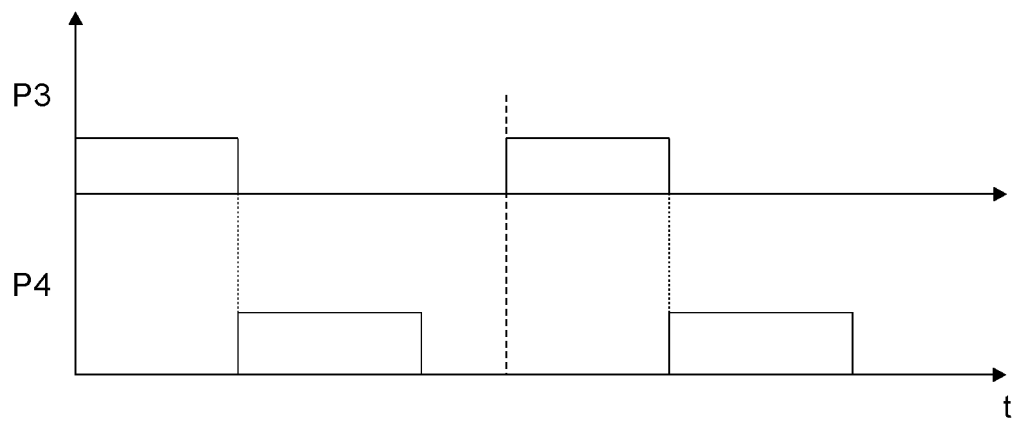


Figure 5

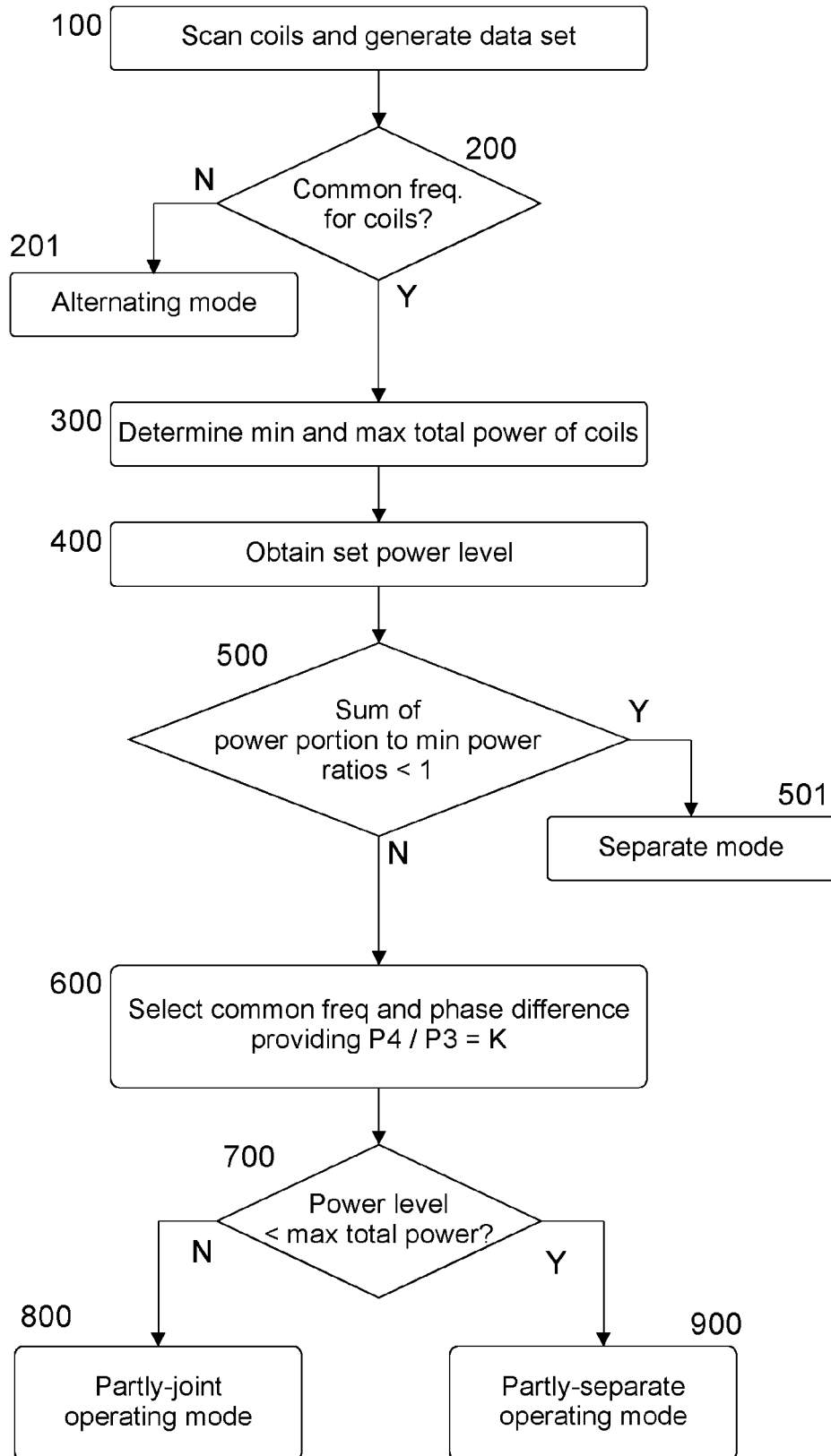


Figure 6

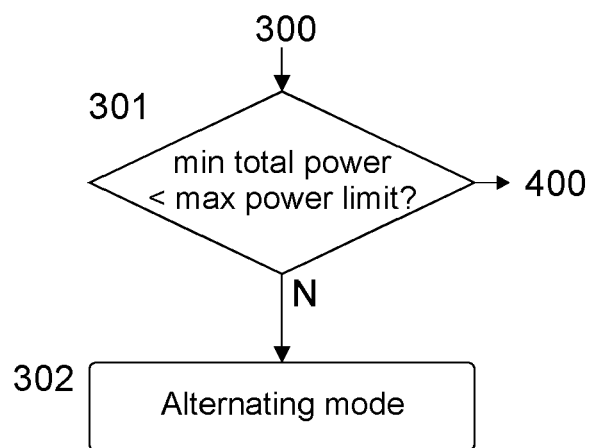


Figure 7



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 7217

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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