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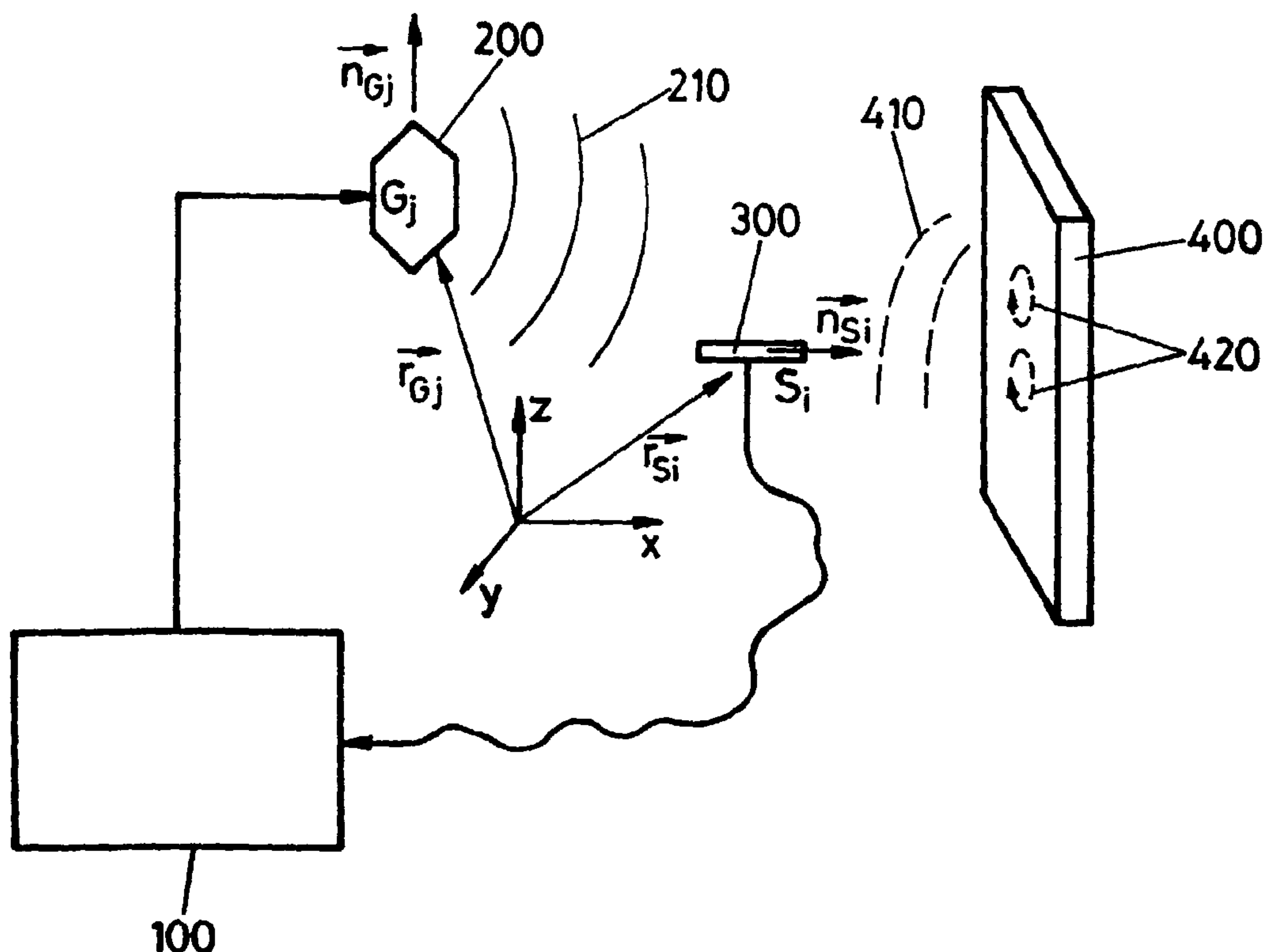
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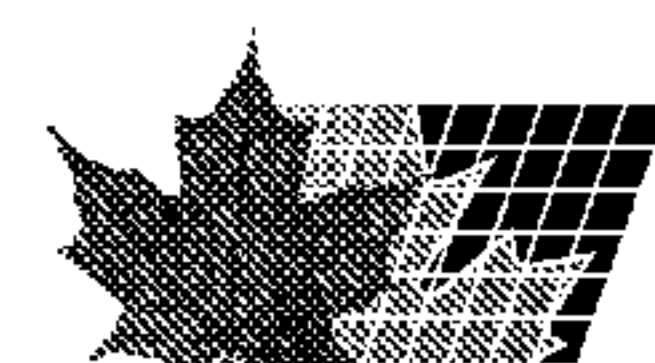
(54) Titre : PROCÉDE POUR DETERMINER LA POSITION D'UN ELEMENT DETECTEUR

(54) Title: METHOD FOR DETERMINING THE POSITION OF A SENSOR ELEMENT



(57) Abrégé/Abstract:

The invention relates to a method for determining the position of a sensor element (300), according to which a magnetic alternating field (210) emitted by at least one field generating unit (200) is measured. The position of the sensor element (300) is determined on the basis of a signal received in the sensor element (300). The inventive method is further characterized in that interference fields (410) are calculated, preferably to a first approximation, said interference fields being caused by eddy currents (420) produced in electrically conductive objects (400). The position that can be determined on the basis of the signal received in the sensor element (300) is corrected on the basis of the calculated interference fields (410).



Abstract

The invention relates to a method for determining the position of a sensor element (300), according to which a magnetic alternating field (210) emitted by at least one field generating unit (200) is measured. The position of the sensor element (300) is determined on the basis of a signal received in the sensor element (300). The inventive method is further characterized in that interference fields (410) are calculated, preferably to a first approximation, said interference fields being caused by eddy currents (420) produced in electrically conductive objects (400). The position that can be determined on the basis of the signal received in the sensor element (300) is corrected on the basis of the calculated interference fields (410).

Method for Determining the Position of a Sensor Element

The present invention relates to a method as defined in the preamble to Patent Claim 1,
5 one application of the method, a device for carrying out the method, and a computer
program related to the foregoing.

In many technical and medical procedures, knowledge of the precise position of a
specific object is critically important. Whereas, in medicine, the position of individual
tissues—for example, a tumour that is to be irradiated in order to be destroyed or to have
10 its growth restricted—has to be determined. Determination of position for inputting into
a computer system is of general importance, for example, for “Cyber Space” applications.
Such an identification position unit or position input unit is also referred to as a three
dimensional mouse in these applications.

A known device and a known method for determining position is described in
15 WO 97/36192 by the present applicant. According to the known theory, an alternating
field is built up with the help of a field generating unit, a plurality of alternating fields
being superimposed one on the other, depending on the number of degrees of freedom of
the sensor element, the position of which is to be determined. The location, and
optionally the position, of the sensor element is determined with the help of a processing
20 and control unit that controls the field generating unit on the one hand and, on the other,
processes the signals received from the sensor element. In this connection, the content of
the publication referred to above forms an integrating component of this description.

It has been shown that in the case of location based on magnetic fields, as applied, for
example, in the known teachings, according to WO 97/36192, eddy currents are

generated in adjacent, electrically conductive objects. These lead to distortion of the original magnetic alternating field, and thus to systemic errors. This means that if the position and orientation of sensor elements were to be determined in a distorted alternating field, as if there were no electrically conductive objects in the vicinity, the
5 values obtained would be systematically falsified.

A method for compensating for the effects of distortion caused by conductive objects is known by the designation "distortion mapping." This method is described in a paper titled "Calibration of Tracking Systems in a Surgical Environment" (Birkfellner et. al., *IEEE Transactions Medical Imaging*, Vol. 17(5), pp. 737 – 742, 1998) In this known
10 method, the position and the orientation of a sensor element is determined with the help of a position measuring system based on position fixing that uses a magnetic field. When this is done, a second position measuring system that is not affected by electrically conductive objects is also used. The difference between the positions and the orientations determined with the two position measuring systems are subsequently used to correct the
15 position and orientation obtained with the help of the position measuring system that is based on the magnetic field. However, this known method entails the disadvantage that—in order to achieve a high level of accuracy—the position and orientation difference has to be measured at as many points as possible. In order to obtain additional points, a costly interpolation method also has to be used. The very high cost is made
20 clear, in particular, by the following example: if a volume of 1m^3 is to be surveyed, with this being done in the three axes, every 10 cm, and at ten different angles of orientation, one obtains 10,000 points. In addition, the second position measuring system already referred to is also necessary.

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In addition, a method for compensating for interference effects is also known; in this, magnetic fields are generated by pulsed DC fields, compensation for eddy current effects being effected in that magnetic field measurements
5 are only conducted after the eddy current fractions contained in the measurement signal have decayed. Continuing explanations of the known method are contained in US-5 453 686 and US-5 767 669. It has been shown that the precision of the results that are obtained is insufficient.
10 In particular, compensation is incomplete if the decay time of the eddy current fractions exceeds the pulse time between two DC pulses. It is true that this can be countered by increasing the pulse time, but this results in an unacceptable lower measurement rate. Furthermore, known
15 compensation methods cannot be used with position measuring systems that are based on magnetic position fixing, which generate magnetic alternating fields.

Thus, it is the objective of embodiments of the present invention to describe a method that ensures improved
20 determination of the position and/or the location of a sensor element.

According to the present invention, there is provided a method for determining the position of a sensor element, which is used to measure a magnetic alternating
25 field emitted by at least one generator unit, the method comprising: receiving a signal in the sensor element, calculating in a first approximation, interference fields, said interference fields arising due to eddy currents generated in an electrically conductive object, and
30 calculating the eddy currents in the object based on the alternating field, and calculating the interference fields, based on the calculated eddy currents, and correcting the

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position that can be determined based on the signal received in the sensor element.

Advantageous configurations of the present invention, provide the use of the method, a device for
5 carrying out the method, and a computer program including program blocks for implementing the method when run on a computer.

The method according to the present invention makes it possible to eliminate or substantially reduce the
10 effects of conductive objects. In addition, this method is more general and more accurate than known methods. Finally, the geometry-dependent

portion of the calculations, in the sense of a system calibration, can be undertaken prior to actual use of the position measuring system.

The present invention will be described in greater detail below on the basis of the drawings appended hereto. These drawings show the following:

5 Figure 1: A diagrammatic view of a known arrangement, comprising a field generator unit, sensor element, and a processing and control unit, with an electrically conductive object;

Figure 2: An electrically conductive object;

Figure 3 A flow chart with some steps of the process for the method according to
10 the present invention.

Figure 1 shows a known arrangement, comprising a field generator unit 200, a sensor element 300, and a processing and control unit 100. In each instance, one side of the processing and control unit 100 is connected by wires to the field generator unit 200, and the other to the sensor element 300. Whereas the field generator unit 200 is preferably
15 located in a known location—which means that the x, y, and z coordinates, including orientation within the system of coordinates are known—the sensor element 300 can be moved as desired, or occupy any position, in any orientation. It is pointed out that it is possible—as described in WO 97/36192—that the sensor element 300 be fixed and the field generator unit 200 be able to move freely, i.e., within the limits imposed by the
20 wires connecting it to the processing and control unit 100. Furthermore, it is also possible that the processing and control unit 100 be realized in a plurality of functional

units, for example, the control unit for controlling the field generator unit 200 be realized in a functional block and the processing unit—in which the actual computation of the position of the sensor element 300 is carried out—be realized in another function block.

These modifications to the arrangement shown in Figure 1 have no effect on the applicability of the method according to the present invention. This also applies to the versions in which a plurality of field generators are provided at different locations, as is taught, for example, by WO 97/36192.

An electrically conductive object, which is taken as being representative of those objects that interfere with fixing the position of the sensor element 300 magnetically, is numbered 400; the object 400 generates eddy currents 420, because of which an interference field 410 that is superimposed on the alternating field 210 is generated.

Before the method according to the present invention is described in greater detail, the following will discuss the general relationships or procedural methods relevant to position fixing that is based on magnetic fields.

As has already been discussed, in magnetic field position fixing, which is also referred to as magnetic position fixing, the position and/or the orientation of one or a plurality of sensor elements 300 relative to one or a plurality of field generator units 200 is determined. The position $\vec{r}_{s_i}$ and orientation $\vec{n}_{s_i}$ of the sensor element S_i can be determined by solving the following system of equations, providing one assumes that the position r_{G_j} and the orientation n_{G_j} of the field generators G_j are known:

$$F_{ij} = F(\bar{r}_{s_i}, \bar{n}_{s_i}, \bar{r}_{g_j}, \bar{n}_{g_j}) \quad (1)$$

wherein i stands for the i -th sensor element and j stands for the j -th field generator unit.

F is a measurement function of at least one component of the magnetic field that depends

5 on the magnetic field $\bar{B}(x, y, z, t)$ (e.g., the induced voltage in a sensor coil). F can, of course, be a function of a plurality of sensors combined within a sensor element, which measures several or all of the components simultaneously.

Depending on the type of solution used for this system of equations, magnetic position fixing systems can be divided into two classes:

10 I. The system of equations is inverted, i.e., the positions of the sensor elements can be computed from the measured magnetic fields:

$$\bar{r}_{s_i} = f_r(F_{ij}) \text{ and } \bar{n}_{s_i} = f_n(F_{ij}) \quad (2)$$

Since inversion of the system of equations is possible only in certain special cases, it is possible to attempt reduction of the field equations into an invertible form by

15 approximation.

II. The system of equations is solved by optimization, i.e., the positions of the sensor elements is varied until the values of F_{ij} best agree with the measured values F_{ij}^M . One possible method would be a Levenberg-Marquardt χ^2 Fit. When this is done, the sensor positions r_{s_i} and $\bar{n}_{s_i}$ are varied until such time as

$$\chi^2(\vec{r}_{s_i}, \vec{n}_{s_i}) = \sum_j \frac{(F_{ij} - F_{ij}^M)^2}{(\Delta F_{ij}^M)^2} \quad (3)$$

is minimal. For further details of the Levenberg-Marquardt method, reference should be made to *Numerical Recipes* (sic) in C, (W. H. Press, S. A. Teukolsky, W. T. Vetterling und B. P. Flannery; Cambridge University Press; 1994) . A combination of both methods
 5 is also possible.

Since the values for F_{ij} depend only on the relative position of the sensor element S_i and of the field generator unit G_j , the roles of sensor element and field generator unit are interchangeable in all magnetic position fixing systems.

If magnetic fields that vary over time are used, then—as previously discussed—these
 10 generate eddy currents 420 in adjacent, electrically conductive objects 400. These in their turn lead to distortion in the original magnetic alternating field 210 and thus to systemic errors when determining position. This means that if the position and orientation of sensor elements within the distorted alternating field are determined as if there were no electrically conductive object 400 present, the values that are obtained are
 15 corrupted.

In one predetermined measurement arrangement, it has been possible to establish that a measurement error of 4 cm can be reduced to less than 1.5 mm by using the method according to the present invention.

In order to permit the use of the method of magnetic position fixing the vicinity of
 20 electrically conductive objects 400, free of the errors induced by these, according to the

present invention, the alternating field distortions and their effect on the determination of the positions of the sensor element and its orientation are determined. If this is done, the systemic errors that occur can be corrected, which means that the accuracy of the position and/or the orientation can be greatly improved.

- 5 In principle, these corrections can be also be arrived at with the help of finite elements technique and the equations of electrodynamics. Compared to the finite elements method, the preferred embodiment of the method according to the present invention is characterized in that a massive reduction of position computation was achieved since much can be computed in advance by way of system calibration.
- 10 The method according to the present invention will be discussed below; for the sake of simplicity, it will be assumed that the object 400 is an electrically conductive plate, i.e., a flat, restricted surface. Objects 400, which have a relevant extent (depth) in the direction of an imaginary line from the field generator unit 200 to the object 400, can also be processed using the method according to the present invention. To this end, the side that
- 15 is proximate to the field generator unit 200 is approximated by a multi-surface structure. This is permissible since the eddy currents 420 extend only a short distance into the surface. For this reason, the depth of a three-dimensional object 400 is irrelevant. For this reason, the object 400 is approximated by a multi-surface structure in the sense discussed heretofore.
- 20 Some considerations that apply to computation of field distortions as they apply to a conductive plate are discussed below. The results can be used analogously in the case of more general object forms. If an electrically conductive object 400 is located in a

magnetic field $\bar{B}_0(x, y, z, t)$, then eddy currents 410 (Figure 1) will be induced in the surface of the object. These eddy currents 410 will give rise to a further magnetic field $\bar{B}'(x, y, z, t)$ which is superimposed on the original magnetic field $\bar{B}_0(x, y, z, t)$ and results in a field $\bar{B}_{Res}(x, y, z, t)$. $\bar{B}_{Res}(x, y, z, t)$ is distorted as compared to the field $\bar{B}_0(x, y, z, t)$. In order to be able to compute this distorted field, it is necessary to know the induced alternating field $\bar{B}'(x, y, z, t)$. The Biot-Savart Law of Electrodynamics (Equation 4) can be used to compute a field $\bar{B}_1(x, y, z, t)$ that describes $\bar{B}'(x, y, z, t)$ closely enough if the local and time history of the eddy currents 410 in the object 400 is known in N different point-form current elements:

$$B_1(\bar{P}_R, t) = \sum_{i=0}^N \frac{\mu_0 \mu_r I_i(t)}{4\pi} \frac{\Delta \bar{s}(t) \times \bar{r}}{r^3} \quad (4)$$

10

wherein $\bar{P}_R = (x, y, z)$ indicates a point in space and the vector $\bar{r}$ points from the current element to the point $\bar{P}_R$. If necessary, prefactors can be introduced and/or can be contained in the total of the factors $\Delta \bar{s}(t)$. A detailed computation of $\bar{B}_1(x, y, z, t)$ by the introduction of longitudinal currents or current per unit area, etc., in place of point currents is possible. This would, however, change the notation used for Equation 4. On the other hand, in most cases, Equation 4 can be used as written above in the event that N is selected so as to be great enough.

15

Thus, the field distortions are computed in two steps. The first step involves determining the eddy currents 410, and the second step involves computation of an interference field

$\bar{B}_1(x, y, z, t)$ which describes the interference field $\bar{B}'(x, y, z, t)$ closely enough.

Figure 2 shows the object 400 which, for purposes of determining the interference field

5 410, is divided into a multi-surface structure consisting of any number of segments.

Initially, the eddy currents are determined on the basis of this division and of various other assumptions.

The eddy currents flow on the surface of the object 400, at a depth of penetration that is "unimportant" for the theory. In order to be able to compute the interference field

10 $\bar{B}'(x, y, z, t)$ referred to above with sufficient accuracy, it is enough to know the time history of the current curve at several points on the surface of the object 400. The number of points depends on the degree of accuracy that is demanded. Thus, the eddy currents are determined at points that lie on or close to the surface of the object.

As a first step, the object is divided into N segments that can be of any shape, these

15 segments best (but not necessarily) covering the whole object. In the following, the segments are designated $S_i \{0 \leq i \leq N-1\}$, wherein i is used as the index. In a second step, a supporting point P_1 is selected for each segment. It is useful, but not essential, to define as many supporting points as there are segments, and assign these unambiguously to the segments. In the following, for purposes of clarity, it is assumed that N segments

20 S_i are each defined with an unambiguously associated supporting point P_i . The current densities $\bar{i}_i(t)$ at the supporting point P_i of each segment S_i are computed by the following formula:

$$\vec{l}_i(t) = \sum_{j=0}^N \vec{l}_{ij}(t) \text{ mit } j \diamond i \quad (5)$$

wherein $\vec{l}_{ij}(t)$ is the current density of the eddy current $I_{ij}(t)$ which is caused by the current change of the field of $\vec{B}_0(x, y, z, t)$ in the segment S_i and which flows through the supporting point P_i or in the vicinity of the supporting point P_i . Computation of the individual eddy currents $I_{ij}(t)$ is described in the following section. Initially:

$$\vec{l}_{ij}(t) = \frac{\vec{\lambda} I_{ij}(t)}{A_s} \quad (5a)$$

wherein $\vec{\lambda}$ is the direction vector (or a direction that is almost colinear to this) of the current line through the supporting point P_i in the supporting point P_i within the supporting point P_i and with A_s being the cross-sectional area of the flow line, wherein

$$A_s = \pi \cdot r^2(h) \quad (5b)$$

with r = the radius of the circular cross-sectional area;

h = the depth of penetration.

If the current densities $\vec{l}_i(t)$ are known then, as an interference field caused by,

$\vec{B}_0(x, y, z, t)$, $\vec{B}_1(x, y, z, t)$ can also be computed; to this end, $\vec{l}_i(t) \cdot A(S_i)$ can be used

directly in Equation 4, when $A(S_i)$ is the area of the segment S_i . In most cases,

$\vec{B}_1(x, y, z, t)$ can be considered to be $\vec{B}'_1(x, y, z, t)$. As a second order effect, $\vec{B}_1(x, y, z, t)$

can be used as the original field in order to once again compute eddy currents for a

second interference field $\vec{B}_2(x, y, z, t)$ (the effect that the eddy currents have on one

another), which is superimposed by $\vec{B}_0(x, y, z, t)$ and $\vec{B}_1(x, y, z, t)$. In the second

approximation, $\vec{B}'(x, y, z, t)$ would be equal to the sum of $\vec{B}_1(x, y, z, t)$ and $\vec{B}_2(x, y, z, t)$.

This iterative process can be continued for effects of any order. It is, however, accurate enough for most applications of first-order effects

An individual eddy current $I_{ij}(t)$ is a current line that flows through the supporting point P_i and is caused by the variations of the current of the field over time, through the supporting point P_i . In order to compute $I_{ij}(t)$, the inductance L_{ij} , its actual resistance R_{ij} and the variation of current over time $\frac{d\phi_j}{dt}$ are required. If these values are known, then

$I_{ij}(t)$ is given by solving the differential equation

$$\frac{d\Phi_j}{dt} - L_{ij} \frac{dI_{ij}(t)}{dt} - R_{ij} I_{ij}(t) = 0 \quad (6)$$

In many cases, $\vec{B}_0(x, y, z, t)$ may be periodic over time, or even oscillate harmonically; this is not essential to the validity of the method according to the present invention.

The inductance L_{ij} and the actual resistance R_{ij} are given by the geometric form of the eddy current $I_{ij}(t)$ and the change of current $\frac{d\phi_j}{dt}$ through the field $\vec{B}_0(x, y, z, t)$ at the point P_j , together with the area of the segment S_j . In the steps that follow, the shape of the eddy current is describe first, and then the inductance L_{ij} and the actual resistance R_{ij} are computed.

Assume that a single magnetic field line B penetrates a small area dA about a point P on the object. In this case, the induced current lines in the vicinity of the point P would be circular, and localization would be effected at the edge of the object 400, which is to say

that it would conform to the shape of the border round the object. The shape of any eddy current is a flow along a contour line of a surface, which satisfies the potential equation

$$\Delta\phi = \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0 \quad (7)$$

wherein $\phi(x, y)$ stands for the potential. The limiting conditions for the unequivocal
 5 solution of Equation 7 (determined from $\phi(x, y)$) can be seen in Figure 2 (namely, ϕ_0 at the edge of the object and ϕ_1 at the point P_j , $\phi_0 < \phi_1$). This potential equation is best solved numerically. With the shape of the eddy current and the depth of penetration h of the current into the material, the individual current line can be regarded as a conductor
 loop with an annular material cross section with the diameter of the depth of penetration
 10 (other appropriate material cross-section geometries are, of course, conceivable, but are not essential for the calculations).

The actual resistance of the conductor loop is thus

$$R = \frac{l\rho}{\left(\frac{h}{2}\right)^2 \pi} \quad (8)$$

wherein R = actual resistance [Ω]

15 l = length of the conductor loop [m]

h = depth of penetration of the current [m]

ρ = specific electrical resistance of the material [Ωm]

The inductance of the conductor loop is given by

$$L = \frac{2W}{i^2} \quad (9)$$

and can be computed numerically, with

$$W = \int_{\text{Raum}} \frac{\vec{B}^2}{2\mu_0} dV \quad (10)$$

standing for the energy stored in the magnetic field generated by the conductor in the event that a current i is flowing in the conductor. There are as many other

5 approximations "as desired," which can replace Equations (8), (9), (10) and provide similar results.

The following applies for computing the flow $\Phi_j(t)$ from the field $\vec{B}_0(x, y, z, t)$:

$$\Phi_j(t) = \vec{B}_0(x, y, z, t) \cdot \vec{A}_j \quad (11)$$

wherein $\vec{B}_0(x, y, z, t)$ is the undisturbed field at the point P_j and $\vec{A}_j$ is the surface normal

10 for the segment S_j , with the amount of the surface of the segment in question. Formula 11 is an approximation formula for the generally valid formula

$$\Phi_j(t) = \int_{A_j} \vec{B}_0(x, y, z, t) d\vec{A} \quad (11a)$$

and can be used if B is sufficiently homogenous over A_j (e.g., for small surfaces A_j). At this point, it should be noted that the surface A_j of the segment S_j does not lie completely

15 within the conductor loop $I_{ij}(t)$ in all cases; corrections could be applied with respect to this, although they are not, as a rule, required.

Computation of the inductance L_{ij} and the actual resistance R_{ij} , which is in part intensive, can be performed in advance using the Formulae (8), (9), and (10), since these depend solely on the geometry and the material of the object—in the sense of a system

20 calibration. The use and solution of Formula (4) and Formula (5) in order to calculate

$\vec{B}_1(x, y, z, t)$ can be done at another time, particularly if the exciter field $\vec{B}_0(x, y, z, t)$ is known. Iterations, such as the use of the field $\vec{B}_1(x, y, z, t)$ to calculate a field $\vec{B}_2(x, y, z, t)$, etc., are possible. Such iterations could be performed in advance, because they are incorporated into the inductances L_{ij} . However, this only makes sense if

5 corrections of a higher order are required on a regular basis.

In practice, during magnetic position fixing, the position and orientation of one or a plurality of sensor elements 300 (Figure 1) are determined in a magnetic field that is generated by one or a plurality of field generator units 200. In the coordinate system that is used, the position of the field generator unit or units is known. In the case of magnetic

10 alternating fields, adjacent electrically conductive objects 400 generate field distortions because of the eddy currents 420 that are induced in the object 300. The method according to the present invention that is used to correct these distortions, the theoretical basis of which is discussed above, is applied as follows: the position of the electrically conductive object 400 within the coordinate system discussed heretofore is either known

15 or is determined by surveying. The object coordinates are input into a computer system that is used to compute the eddy currents 420 and the resulting field distortions, this being done in such a way that the location coordinates used in the formulae cited above are defined in the coordinate system defined by the field generator unit 200. The computer system is then used to compute the interference field generated by the eddy currents 420.

20 When the eddy currents 420 are taken in to account, the Equation system 1 changes as follows:

$$F_y = F(\vec{r}_s, \vec{n}_s, \vec{r}_G, \vec{n}_G) + \sum_{k=1}^p F'_k(\vec{r}_s, \vec{n}_s, \vec{r}_G, \vec{n}_G) \quad (12)$$

wherein F_{ij} stands for the interference generated by the eddy currents 420 of the object k . P stands for the number of objects. The manner in which this correction is used depends of the type of magnetic position fixing system that is used.

- I. In systems that are based on Equation 2, the measured values are corrected iteratively,
5 i.e., one initially computes the undisturbed solution according to Equation 2. The corrected F' can be computed using the position of the sensor element 300 and subtracted from the measurements F_{ij}^M . A position is computed again, using the corrected measurements. This algorithm is repeated until the variations of the computed positions are beneath specific tolerance thresholds.
- 10 II. The solution algorithm does not have to be altered in systems that are based on Equation 3. In the Chi^2 sum, the magnetic field with corrections for eddy currents according to Equation 12 is used in place of the model for corrected magnetic field F_{ij} that are free of eddy currents.
- III. Subject to certain preconditions, it may also be possible to invert the Equation
15 System 12, which then leads to a solution corresponding to Equation 2.

Figure 3 is a simplified version of a flow chart for a computer program that is based on the method according to the present invention. The individual steps have already been described on the basis of Figure 1 and Figure 2.

The method according to the present invention can also be used for objects that contain
20 openings (holes), when the number L of openings can have any value. When this is done, for the solution methods that have already been described, the boundary conditions of the

potential equation (7) at the edges of the openings must be equal to the potential ϕ_0 at the edge of the object. Furthermore, N plus L (N = number of supporting points and L = number of openings) current lines I_{ik} are added to the methods that have been described, and these must be added to the sum (5) (k varies from 1 to L).

- 5 Individually, the additional eddy current lines I_{ik} can be calculated analogously to the eddy current lines L_{ij} , i.e., solution of the potential equation (7) for the shape of the flow and computation of the inductance and of the resistance according to Equation (8) and Equation (9). However, in the case of potential equation (7), it should be noted that the limiting condition is not " ϕ_l at the edge of the opening k ." In the case of large openings,
- 10 Formula 11a will possibly be used in place of the approximation formula 11 in order to compute the current.

Individual conductor loops can also be computed with this method, since the openings discussed above can be expanded as desired close to the border of the object that is being computed. The simplest example is a ring, which can be regarded as a disk with an

15 almost equally large opening: in this example the current lines I_{ij} are negligible (the supporting points could be omitted), and there is only one I_{ik} , whose form is determined by the ring. In the event that the supporting points are omitted, the field B_i is to be determined by the linear integral, by way of Equation 4.

One further aspect is that interference effects from unknown objects are screened,

20 because a conductive plate is interposed between the field generator unit and the object, the size, shape, and position of said plate being known. Thus, the field distortions of this plate have to be taken into account, even though none of the other electrically

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conductiveobjects that are located on the other side of the plate relative to the field generator unit need be taken into account because of the shielding.

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Key to Figure 3: (From top to bottom)

Box No. 1: Select segments and supporting points

Box No. 2: Compute inductances and resistances

Box No. 3: Insert fields and compute currents

5 Box No. 4: Compute interference fields

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CLAIMS:

1. A method for determining the position of a sensor element, which is used to measure a magnetic alternating field emitted by at least one generator unit, the method comprising:

- 5 receiving a signal in the sensor element,
- calculating in a first approximation, interference fields, said interference fields arising due to eddy currents generated in an electrically conductive object, and
- calculating the eddy currents in the object based on the alternating field, and
- 10 calculating the interference fields, based on the calculated eddy currents, and
- correcting the position that can be determined based on the signal received in the sensor element.

2. The method according to claim 1, wherein to further improve the
- 15 determination of a position, at least one additional iteration is performed, comprising

calculating additional eddy currents in the object based on calculated interference fields, and

calculating additional interference fields based on the additional eddy currents.

- 20 3. The method according to claim 1 or 2, further comprising:

determining the position and shape of the object;

calculating resistances in the object according to $R = \frac{l\rho}{\left(\frac{h}{2}\right)^2 \pi}$; and

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calculating inductances in the object according to $L = \frac{2W}{i^2}$.

4. The method according to claim 3, further comprising:

performing an additional iteration to further improve the inductances, the performing comprising:

5 calculating additional eddy currents in the object based on the calculated interference fields, and

determining additional inductances based on the additional eddy currents.

5. The method according to claim 3 or 4, wherein the determination of the position and shape of the object and the determination of the resistances and inductances in the object take place in advance, as a system calibration; i.e., prior to the calculations that take into account the alternating field.

6. The method according to any one of claims 1 to 5, wherein the following procedure is followed for determining the eddy currents:

15 the object is divided into segments (S_i) and interpolation nodes (P_i);

the current density (i_i) in the interpolation nodes (P_i) is determined; and

the eddy currents (I_{ij}) are determined from the current densities (i_i).

7. Device for using the method as defined in any one of claims 1 to claim 6, wherein at least one field generator, at least one sensor element, and a processing and control unit are provided, the field generator unit and the sensor element being connected to the processing and control unit.

8. Device as defined in claim 7, wherein at least one electrically conductive object is provided in order to shield the field generator unit.

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9. A computer readable medium containing program blocks, which when executed on a computer perform the steps as defined in any one of claims 1 to 6.

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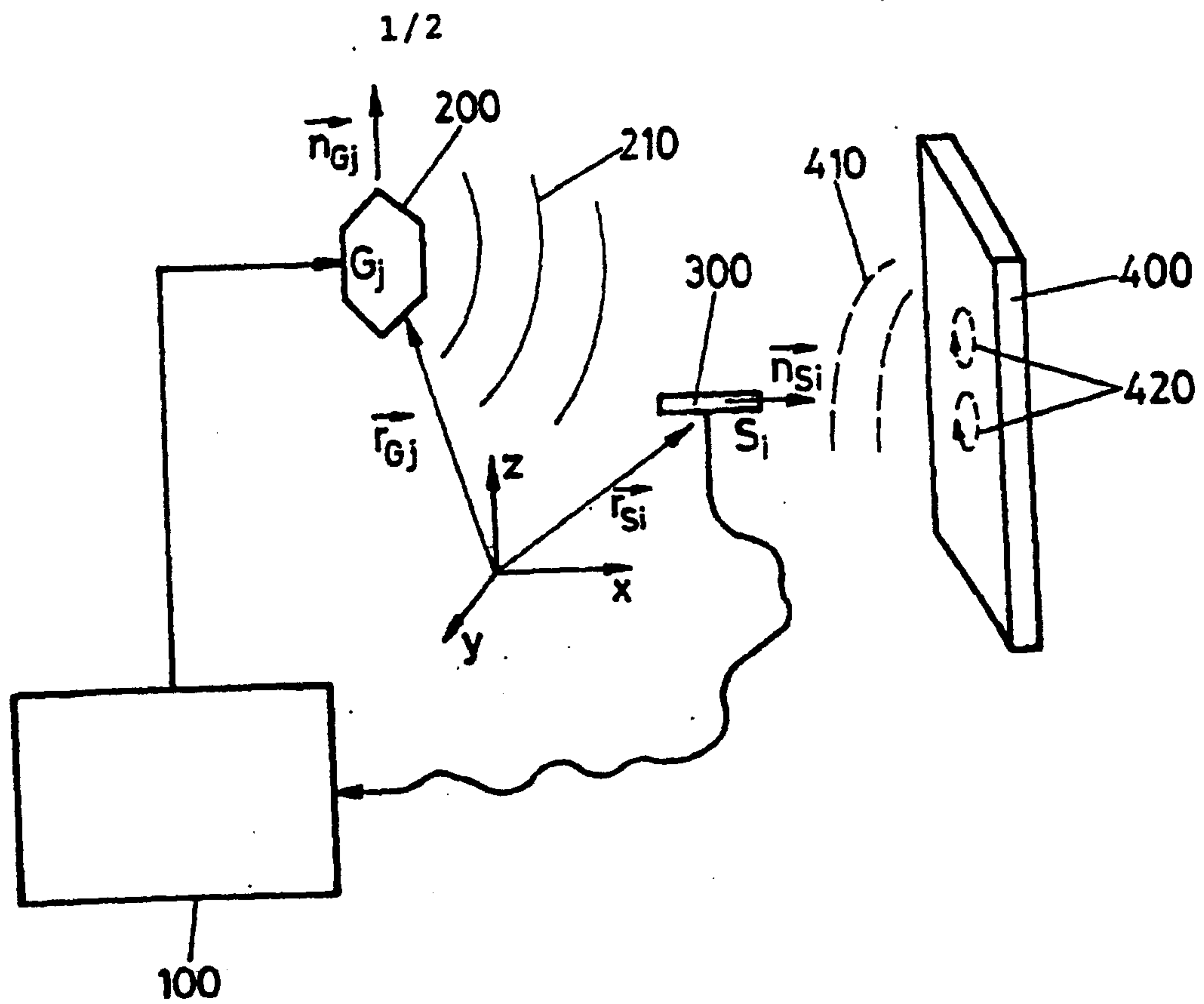


FIG.1

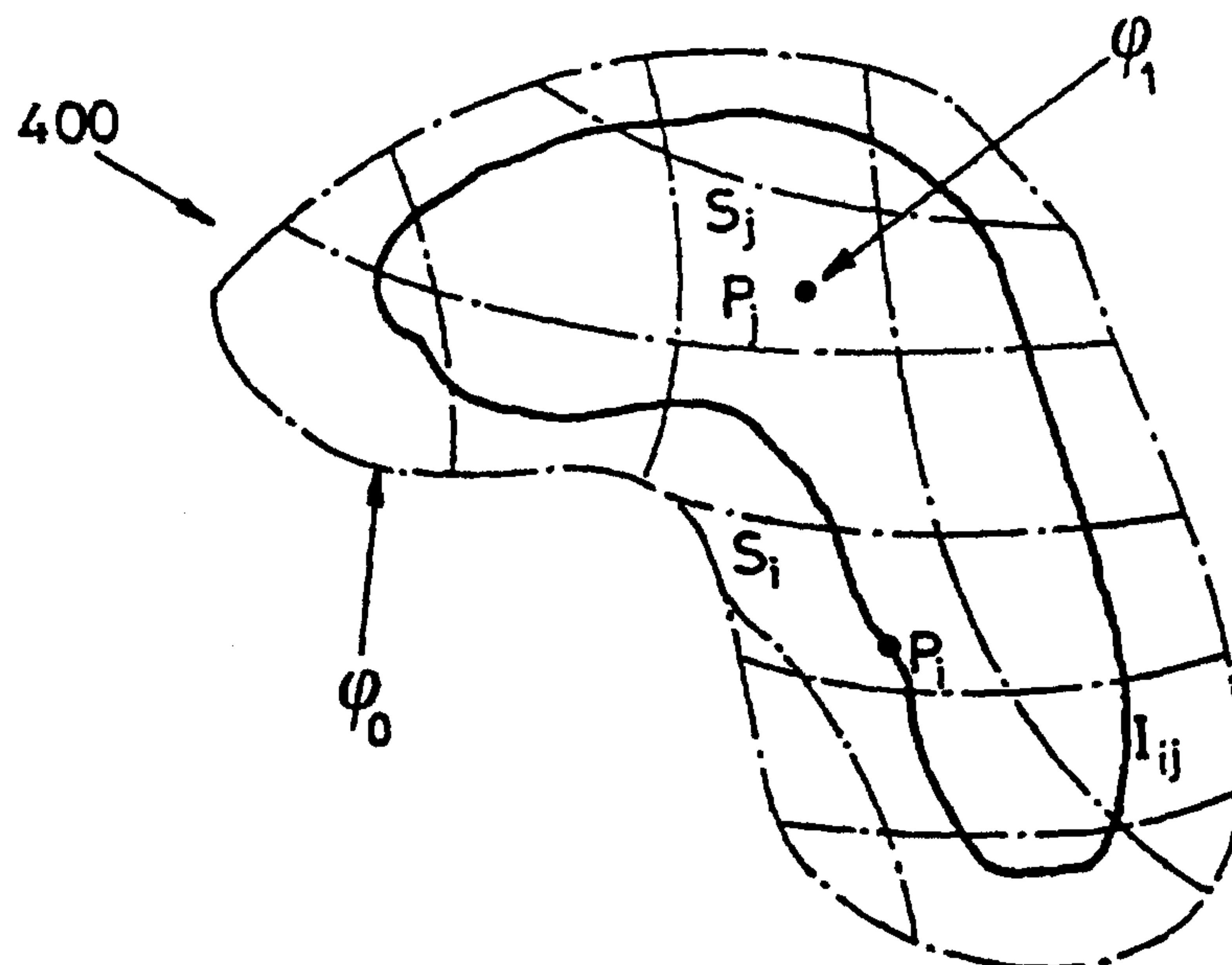


FIG.2

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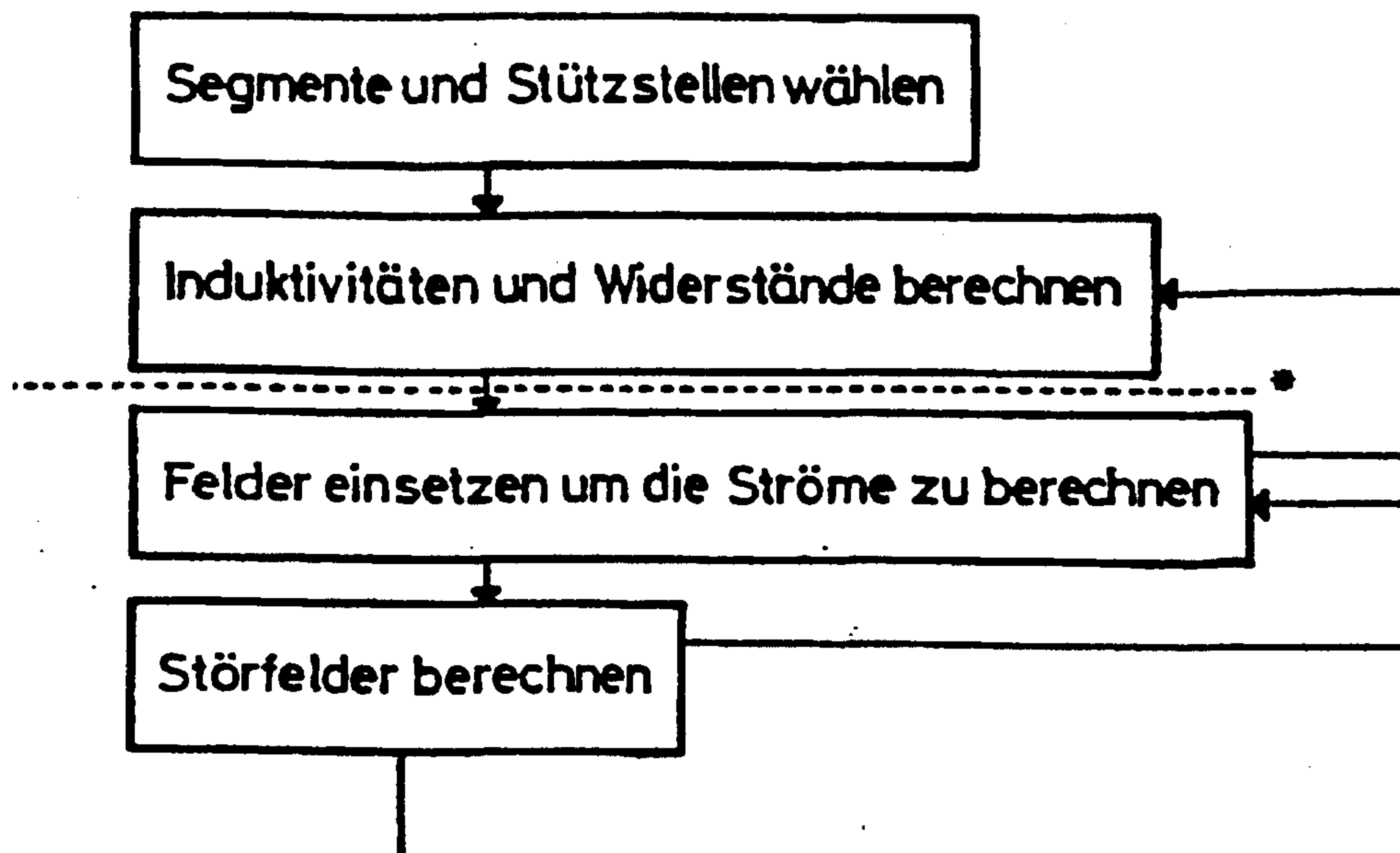


FIG. 3

