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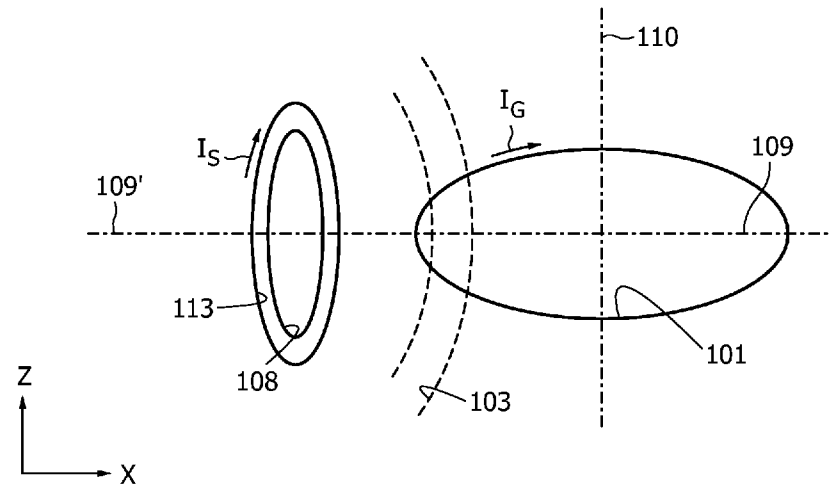

(57) Abstract: The present invention relates to a system (100) and method of inductively measuring the bio-impedance of a conductive tissue (106). Furthermore the invention relates to a computer program (115) for operating such a system (100). In order to provide a fast, simple and reliable adjustment technique for an inductively bio- impedance measuring system (100) with separate generator and sensor coils (101, 108; 117) a system (100) is suggested, the system (100) comprising a generator coil (101) adapted for generating a primary magnetic field, said primary magnetic field inducing an eddy current in the conductive tissue (106), a separate sensor coil (108; 117) adapted for sensing a secondary magnetic field, said secondary magnetic field being generated as a result of said eddy current, with the axis (109) of the sensor coil (108; 117) being orientated substantially perpendicular to the flux lines of the primary magnetic field (103), and a shimming coil (113; 120) adapted for generating a tertiary magnetic field in a way that in the sensor coil (108; 117) the primary magnetic field is cancelled out.

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System and method for inductively measuring the bio-impedance of a conductive tissue

The present invention relates to a system and method for inductively measuring the bio-impedance of a conductive tissue. Furthermore the invention relates to a computer program for operating such a system.

The inductive measurement of bio-impedances is a known method to determine various vital parameters of a human body in a non-contact way. The operating principle is the following: Using a generator coil, an alternating magnetic field is induced in a part of the human body. This alternating magnetic field causes eddy currents in the tissue of the body. Depending on the type and conductivity of the tissue, the eddy currents are stronger or weaker. The eddy currents cause a secondary magnetic field, which can be measured as an induced voltage in a sensor coil.

The inductive measurement of the bio-impedance has been shown to allow the non-contact determination of several parameters, e.g. breath action and depth, heart rate and change of the heart volume and blood glucose level, as well as fat or water content of the tissue.

In order to enhance the sensitivity and the signal to noise ratio (SNR) of such measuring systems, different coil arrangements have been proposed for magnetic field compensation. However, in practice a large effort is being devoted to manually adjust the coils (e.g. using adjustable mounting screws) to reach an optimal setup. Furthermore said adjustment has to be repeated if the sensor system is moved or changed.

It is an object of the present invention to provide a fast, simple and reliable adjustment technique for an inductively bio-impedance measuring system with separate generator and sensor coils.

This object is achieved according to the invention by a system for inductively measuring the bio-impedance of a conductive tissue, the system comprising

a generator coil adapted for generating a primary magnetic field, said primary magnetic field inducing an eddy current in the tissue, a separate sensor coil adapted for sensing a secondary magnetic field, said secondary magnetic field being generated as a result of said eddy current, with the axis of the sensor coil being orientated substantially perpendicular to the flux lines of the primary magnetic field, and a number of shimming coil adapted for generating a tertiary magnetic field in a way that in the sensor coil the primary magnetic field is cancelled out.

The object of the present invention is also achieved by a method for inductively measuring the bio-impedance of a conductive tissue, the method comprising the steps of: arranging a generator coil and a separate sensor coil, with the axis of the sensor coil being orientated substantially perpendicular to the flux lines of a primary magnetic field generated by means of the generator coil, said primary magnetic field inducing an eddy current in the conductive tissue, sensing a secondary magnetic field by means of the sensor coil, said secondary magnetic field being generated as a result of said eddy current, and generating a tertiary magnetic field by means of a shimming coil in a way that in the sensor coil the primary magnetic field is cancelled out.

The object of the present invention is also achieved by a computer program for operating a system for inductively measuring the bio-impedance of a conductive tissue, the system comprising a generator coil adapted for generating a primary magnetic field, said primary magnetic field inducing an eddy current in the tissue, a sensor coil adapted for sensing a secondary magnetic field, said secondary magnetic field being generated as a result of said eddy current, with the axis of the sensor coil being orientated substantially perpendicular to the flux lines of the primary magnetic field, and a shimming coil, the program comprising computer instructions to automatically control the shimming coil to generate a tertiary magnetic field in a way that in the sensor coil the primary magnetic field is cancelled out. The technical effects necessary according to the invention can thus be realized on the basis of the instructions of the computer program in accordance with the invention. Such a computer program can be stored on a carrier such as a CD-ROM or it can be available over the Internet or another computer network. Prior to being executed, the computer program is loaded

into the computer by reading the computer program from the carrier, for example by means of a CD-ROM player, or from the Internet, and storing it in the memory of the computer. The computer includes inter alia a central processor unit (CPU), a bus system, memory means, e.g. RAM or ROM etc., storage means, e.g. floppy disk or hard disk units etc. and input/output units. Alternatively the inventive method could be implemented in hardware, e. g. using one or more integrated circuits.

A core idea of the invention is to complete the mechanical adjustment of the sensor coil (as known from the prior art) with an additional electronic adjustment. Said electronic adjustment can be automated and performed in situ during operation of the system.

The invention suggests that the sensor coil is mechanically arranged in a way that the native (primary) magnetic field generated by the generator coil is cancelled out as far as possible in the sensor coil and only the (secondary) magnetic field generated by eddy currents in the conductive tissue is sensed. In other words, the generator coil and the sensor coil are arranged beforehand, preferably during the installation setup of the system, in a way that approximately no magnetic net flux from the generator coil passes through the sensor coil. In other words, inside the sensor coil the primary magnetic field lines are substantially (i.e. nearly) tangential to the sensor coil, i.e. inside the sensor coil the axis of the sensor coil is substantially perpendicular to the magnetic field lines of the primary magnetic field. During operation of the system, the conductive tissue creates a secondary magnetic flux through the sensor coil, which is not zero. However, the primary magnetic flux through the sensor coil will not be precisely zero because of the influence of temperature or modifications of the coil position etc. during operation of the system.

Now, according to the invention, the sensor coil is provided with a shimming coil for electronic adjustment. Into the shimming coil a defined current is injected. The amplitude of the current is adjusted such that the (tertiary) magnetic field generated by the shimming coil completely cancels the native (primary) magnetic field. Thus, the resulting magnetic flux (net flux) of the primary magnetic field through the sensor coil is made zero. Only the tertiary magnetic field originating from the eddy

current in the conductive tissue is sensed by the sensor coil. This way the sensitivity of the sensor coil and the signal to noise ratio (SNR) of the sensing arrangement is improved significantly and the manufacturing effort is reduced to allow a low cost mass production. With the invention a fast, simple and reliable adjustment technique is provided. No extensive (manual) sensor adjustment is necessary.

The term "conductive tissue" has to be understood as conductive organic material, e.g. a body of a human or animal or, a plant. Furthermore the term "conductive tissue" comprises substances, like water, muscle, fat, blood or cerebrospinal fluid (CSF). "Conductive tissue" further comprises non-organic conducting or low conducting tissue of any kind, in particular for material testing.

The invention can be used with a contactless medical diagnostic system that measures inductively the bio-impedance of a user's body. Such a system allows an easy and comfortable diagnosis of vital parameters like the heart rate, tissue water content or blood glucose level to supervise a user without the need of applying any kind of devices to the user's body. This method can also be used to measure the position of the user, the breathing frequency, movement etc.

It will be evident to those skilled in the art that the invention is not limited to a system and method using just one generator coil, one sensor coil and one shimming coil. The invention can be realized using a larger number of sensor coils together with a corresponding number of shimming coils. Furthermore the invention can be realized using more than one generator coil.

In particular if a large number of measuring data is needed, a larger number of generator coils, sensor coils and shimming coils (e.g. 4, 8, 16 or 32 or any other kind of coil combinations) may be employed. The coils are then preferably arranged in form of an array or a matrix or any other way that the primary field is canceled out. Such a larger number of coils may be used e.g. in order to implement a magnetic induction tomography (MIT) system or a multi channel system for monitoring, e.g. because different parts of the user's lungs need to be monitored e.g. due to oedema development in the lungs.

These and other aspects of the invention will be further elaborated on the

basis of the following embodiments which are defined in the dependent claims.

According to a preferred embodiment of the invention the shimming coil and the sensor coil are located in a way that the axis of the shimming coil is orientated parallel to the axis of the sensor coil. In this way the shimming coil allows to create a magnetic flux in direction of the primary magnetic field and so cancels out the resulting magnetic field.

According to another preferred embodiment of the invention the shimming coil is implemented as one or more auxiliary windings of the sensor coil. This way sensor coil and shimming coil can be integrated into a single component, which reduces manufacturing costs and time and effort for coil setup.

According to another preferred embodiment of the invention a control unit for controlling the shimming coil is connected to the shimming coil, said control unit being adapted for providing a shimming current to the shimming coil. Said control unit is preferably adapted for receiving a partial amount of the current of the generator coil in order to apply this current to the shimming coil. Because a fraction of the generator coil current is applied to the shimming coil, the field of the generator coil and the field of the shimming coil show a phase difference of 180°. Using the induced signal in the generator coil allows to cancel the resulting flux of the primary magnetic field locally in the sensor coil using an electronic way. In other words the current of the shimming coil can be adjusted electronically (and preferably automatically) using the control unit. Furthermore in this way the signal in the sensor coil can be (automatically) minimized if no tissue is near the measurement system.

According to another preferred embodiment of the invention, the control unit comprises a controllable potentiometer or a controllable resistor for adjusting the amplitude of the shimming current, thereby being controlled by the control unit. Thus, the electronic adjustment can be performed using a very simple setup.

According to another preferred embodiment of the invention the control units comprise a phase shifter module adapted for shifting the phase of the shimming current. Thus parasitic (e.g. capacitive) effects due to measuring conditions can be compensated in an easy way.

According to another preferred embodiment of the invention the shimming coil is considerably smaller than the generator coil and/or the shimming current applied to the shimming coil is very low compared to the generator coil current applied to the generator coil. By this means it can be assured, that there are no or only negligible eddy currents produced by the shimming coil. Such eddy currents would effect the measuring and impair the SNR of the measurement.

According to yet another preferred embodiment of the invention the sensor coil is a SMD (surface mounted device) coil attached to a printed circuit board by means of two attachment points and the shimming coil comprises a number of PCB (printed circuit board)-tracks and a corresponding number of wires, with said PCB-tracks being positioned between said two attachment points and beneath said SMD coil and said wires running across said SMD coil. With such an embodiment a cheap and small sensor unit can be achieved with an electronically adjustable sensor coil.

These and other aspects of the invention will be described in detail hereinafter, by way of example, with reference to the following embodiments and the accompanying drawings; in which:

Fig. 1 shows a schematic view of coils in coaxial alignment (prior art),

Fig. 2 shows a schematic view of coils without conductive tissue in a normal alignment (prior art),

Fig. 3 shows another schematic view of coils with conductive tissue in a normal alignment (prior art),

Fig. 4 shows a schematic view of a measuring system according to the invention,

Fig. 5 shows a schematic block diagram of a measuring system according to the invention,

Fig. 6 shows a schematic view of coils in a normal alignment according to the invention,

Fig. 7 shows a schematic view of coils in another alignment according to

the invention, and

Fig. 8 shows a schematic view of an embodiment of the invention realized in SMD technique.

Fig. 1 illustrates the general principle of measuring eddy currents in a conductive tissue of a user's body using an axial alignment of a generator coil 1 and a sensor coil 2 as known from the prior art. An alternating current is fed into the generator coil 1 and produces an alternating primary magnetic field 3 (in all figures the flux lines are shown representing the magnetic field). The sensor coil 2, being axially aligned with the generator coil 1, senses the primary magnetic field 3. The axis 4 is shown as dot and dash line. If the primary alternating magnetic field 3 passes through a conducting material, e.g. tissue 6 of the user's body, eddy currents 5 are induced. The eddy currents 6 are illustrated schematically in form of a loop. These eddy currents 5 will also produce an alternating secondary magnetic field 7 (dotted lines). As a result the sensor coil 2 measures the primary and the secondary (i.e. a perturbed) field.

If such a coil arrangement is used in a magnetic induction tomography (MIT) system, reducing the effect of the primary magnetic field 3 will help to increase the sensitivity and the SNR (signal to noise ratio) of the measurement. The primary magnetic field 3 can approximately be cancelled using different specific sensor alignments. In one of those field compensation schemes a high sensitivity is achieved in that a sensor coil is intended to be arranged such that the primary magnetic field 3 does not induce a signal in the sensor coil. The aim of this approach is that only eddy currents 5 in the conductive tissue 6 may induce a signal.

For multi-channel systems, the adoption of a planar array geometry in principle allows primary magnetic field compensation for all combinations of generator coil and sensor coil. In Fig. 2 (prior art) a normal (i.e. vertical) alignment is shown with no conductive tissue in measuring position as known from the prior art. The generator coil 1 and the sensor coil 8 are placed on a common plane (XZ-plane), with the axis 9 of the sensor coil 8 orientated perpendicular to the axis 10 of the generator coil 1. At the

same time the axis 9 of the sensor coil 8 is orientated substantially perpendicular to the flux lines of the primary magnetic field 3, such that approximately no net flux from the generator coil 1 passes through the sensor coil 8. In other words, the sensor coil 8 is aligned with respect to the generator coil 1 in a way that the flux lines of the primary magnetic field 3 are substantially tangential (90°) to the axis 9 of the sensor coil 8. In Fig. 2 there is no medium in measuring position. In Fig. 3 (prior art) there is conducting tissue 6 of the body of a user in a measuring position. The conductive tissue 6 is of the plane and therefore creates a secondary magnetic field 7 and a secondary magnetic flux, which is not zero. The secondary magnetic flux can be sensed in the sensor coil 8. Such a sensor arrangement is also called B_X sensor or normal alignment, since the sensor coil 8 is adapted to measure a magnetic flux in X-direction. In Fig. 3 the flux lines of the primary magnetic field 3 are not shown for the reason of clarity. However, the primary and secondary magnetic fields 3, 7 are superposing each other.

From the prior art it is known to adjust the position of the coils 1, 8, in particular the position of the sensor coil 8, by means of adjustable plastic screws (not shown). In other words, in order to increase the SNR the signal of the primary magnetic field 3 has to be reduced by turning the screws. However, by this means a coil alignment can be reached, which is only substantially (i.e. nearly) perpendicular.

In Fig. 4 a simplified and schematic view of a measurement system 100 for inductively measuring the bio-impedance of a conducting tissue 106 within the body of a user according to the present invention is given. For example the system 100 may be a tomographic system adapted to use bio-impedance measurements in a tomographic way to obtain a conductivity distribution over time in a user's body in two or three dimensions or as a single image. In another example the system 100 may be a bed for monitoring a user by means of bio-impedance measurement. In another example the system 100 may be adapted for performing a single channel or multi channel measurement, e.g. for monitoring vital signs of a user. From measurements over time, certain characteristics, like volume changes of the heart or lungs of the user can be calculated. In the following description analyzing units or other components of the system 100 which are employed for evaluating the measurement results are not

described further. However, in order to obtain feasible results, such analyzing components have to be used together with the described measuring components.

The conductive tissue 106 is positioned on a support 111, e.g. a bed or a measuring desk. Near the tissue106 the measuring unit 112 is positioned, said measuring unit 112 comprising a generator coil 101 adapted for generating a primary magnetic field 103 (flux lines are shown as dotted lines), a separate sensor coil 108 adapted for sensing a secondary magnetic field, a shimming coil 113 adapted for generating a tertiary magnetic field and a control unit 114 adapted for controlling the shimming coil 113, said control unit 114 being connected to the shimming coil 113, see Fig. 5.

The control unit 114 comprises a computer system with functional modules or units, which are implemented in form of hardware, software or in form of a combination of both hardware and software. The computer system may comprise a microprocessor or the like and a computer program 115 in form of software, which can be loaded into the computer. Alternatively the computer program 115 is realized in form of a hardwired computer code. The computer program 115 comprises computer instructions in order to control the shimming coil 113 according to the invention. In particular the computer program 115 comprises computer instructions to control the amplitude and/or phase of the shimming current I_S. Alternatively the control unit may comprise an analogue control circuit for controlling the shimming coil 103. The analogue control circuit preferably comprises a transistor and/or an operating amplifier.

As illustrated in Fig. 6, generator coil 101 and sensor coil 108 are arranged on a common plane (XZ plane) and the axis 109 of the sensor coil 108 again is orientated perpendicular to the axis 110 of the generator coil 101 (normal alignment). Inside the sensor coil 108 the axis 109' of the sensor coil 108 is nearly perpendicular to the flux lines of the primary magnetic field 103. In the generator coil 101 an alternating current I_G is applied in order to generate a primary magnetic field 103. The primary magnetic field 103 induces an eddy current in the tissue 106 of the user's body and a secondary magnetic field is generated as a result of said eddy current (not shown in Fig. 6). In principle the primary and secondary magnetic fields exhibit the same shape as

illustrated in Figs. 2 and 3.

In Fig. 7 another embodiment of the system according to the invention is shown. In contrast to the very symmetric coil arrangement of Fig. 6, the sensor coil 108 and generator coil 101 are now positioned to each other in a non-symmetric way. More precisely, the sensor coil 108 (and the shimming coil 113 corresponding to the sensor coil 108) are rotated with respect to the generator coil 101. However, inside the sensor coil 108 the axis 109 of the sensor coil 108 is still substantially perpendicular to the flux lines of the primary magnetic field 103. Thus, using the shimming coil 113 (the axis 109' of the shimming coil being still parallel to the axis 109 of the sensor coil 108) the primary magnetic field 103 can be cancelled out in the sensor coil 108. As a result, in the sensor coil 108, only the secondary magnetic field 107 is sensed, said secondary magnetic field 107 being generated by the eddy currents 105 in the tissue 106 to be measured. In this embodiment the sensor coil 108 has not to be necessarily on the same plane as the generator coil 101. However, generator coil 101 and sensor coil 108 can be located on the same XZ plane.

The shimming coil 113 is implemented as an auxiliary winding of the sensor coil 108. In other words the shimming coil 113 is located around the sensor coil 108. The shimming coil 113 is arranged in a way that in the sensor coil 108 the primary magnetic field 103 is cancelled out, if the shimming current I_S is set accordingly. For this purpose the shimming coil 113 and the sensor coil 108 are located on a common plane, with the axis 109' of the shimming coil 113 orientated parallel to the axis 109 of the sensor coil 108 for creating a magnetic flux in direction of the primary magnetic field 103.

The control unit 114 is adapted for providing a shimming current I_S to the shimming coil 113. For this purpose the control unit 114 is connected to the generator coil 101 for receiving a partial amount of the current I_G of the generator coil 101. That partial amount (I_S = a I_G , wherein a is a gain coefficient) of the current I_G is then applied to the shimming coil 113. Thereby the amplitude of the current I_S to be supplied to the shimming coil 113 is automatically adjusted until the primary magnetic flux through the sensor coil 108 is zero. The adjustment is performed electronically and

computer controlled using the control unit 114. For this purpose the control unit 114 measures the induced voltage in the sensor coil 108 and controls the amplitude of the shimming current I_S until the induced voltage is zero. For optional controlling the phase of the shimming current I_S the control unit 114 comprises a phase shifter module 116.

If the control unit 114 is implemented without the use of a computer software, the electronic adjustment may be performed automatically using a hardware based control unit or an analogue control circuit. The phase shifting mechanism can also be implemented in form of a hardware module.

Because the shimming coil 113 is considerably smaller than the generator coil 101 and the shimming current I_S applied to the shimming coil 113 is very low compared to the generator coil current I_G applied to the generator coil 101 there are no eddy currents produced by the shimming coil 113.

A sensor coil adjustment as described above will preferably be carried out before each bio-impedance measurement, since between two measurements the measuring conditions might have been changed because of a temperature change or the like.

If tissue of a patient is to be measured, a setting to zero point can be performed. For this purpose the patient, e.g. laying on a bed, is asked to stop breathing and during this rest position the resulting measuring signal is regulated to zero by means of the shimming coil 113. As a result, field signals originating from eddy currents of the patient's rest position are suppressed.

In a preferred embodiment of the invention as illustrated in Fig. 8, the sensor coil is an SMD coil 117 attached to a printed circuit board 118 by means of two attachment points 119. The shimming coil 120 comprises a PCB-track 121 and a wire 122. The PCB-track 121 is positioned between said two attachment points 119 and runs beneath the SMD coil 117 and said wire 122 runs across the SMD coil 117. Alternatively a larger number of PCB-tracks 121 can be used. In this case the number of wires 122 has to be adapted accordingly.

It will be evident to those skilled in the art that the invention is not limited to the details of the foregoing illustrative embodiments, and that the present

invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. It will furthermore be evident that the word "comprising" does not exclude other elements or steps, that the words "a" or "an" do not exclude a plurality, and that a single element, such as a computer system or another unit may fulfil the functions of several means recited in the claims. Any reference signs in the claims shall not be construed as limiting the claim concerned.

REFERENCE NUMERALS

1	generator coil
2	sensor coil
3	primary magnetic field
4	axis
5	eddy current
6	tissue
7	secondary magnetic field
8	sensor coil
9	axis sensor coil
10	axis generator coil
100	system
101	generator coil
102	(free)
103	primary magnetic field
104	(free)
105	eddy current
106	tissue
107	secondary magnetic field
108	sensor coil
109	axis sensor coil
110	axis generator coil
111	support
112	measuring unit
113	shimming coil
114	control unit
115	computer program
116	phase shifter module

117	SMD coil
118	printed circuit board
119	attachment point
120	shimming coil
121	PCB-track
122	wire

CLAIMS:

1. A system (100) for inductively measuring the bio-impedance of a conductive tissue (106), the system (100) comprising

- a generator coil (101) adapted for generating a primary magnetic field (103), said primary magnetic field (103) inducing an eddy current in the conductive tissue (106),

- a separate sensor coil (108; 117) adapted for sensing a secondary magnetic field, said secondary magnetic field being generated as a result of said eddy current, with the axis (109) of the sensor coil (108; 117) being orientated substantially perpendicular to the flux lines of the primary magnetic field (103), and

- a shimming coil (113; 120) adapted for generating a tertiary magnetic field in a way that in the sensor coil (108; 117) the primary magnetic field (103) is cancelled out.

2. The system (100) as claimed in claim 1, characterized in that the shimming coil (113; 120) and the sensor coil (108; 117) are located in a way that the axis (109') of the shimming coil (113; 120) is orientated parallel to the axis (109) of the sensor coil (108; 117).

3. The system (100) as claimed in claim 1, characterized in that the shimming coil (113) is implemented as a number of auxiliary windings of the sensor coil (108).

4. The system (100) as claimed in claim 1, characterized in that a control unit (114) for controlling the shimming coil (113; 120) is connected to the shimming

coil (113; 120), said control unit (114) being adapted for providing a shimming current (I_S) to the shimming coil (113; 120).

5. The system (100) as claimed in claim 4, characterized in that the control unit (114) is adapted for applying a partial amount (aI_G) of the generator coil current (I_G) to the shimming coil (113; 120).

6. The system (100) as claimed in claim 4, characterized in that the control unit (114) comprises a controllable potentiometer or a controllable resistor for adjusting the amplitude of the shimming current (I_S).

7. The system (100) as claimed in claim 4, characterized in that the control unit (114) comprises a phase shifter module (116) adapted for shifting the phase of the shimming current (I_S).

8. The system (100) as claimed in claim 1, characterized in that the shimming coil (113; 120) is considerably smaller than the generator coil (101) and/or the shimming current (I_S) applied to the shimming coil (113; 120) is very low compared to the generator coil current (I_G) applied to the generator coil (101).

9. The system (100) as claimed in claim 1, characterized in that the sensor coil (108; 117) is a surface mounted device coil (117) attached to a printed circuit board (118) by means of two attachment points (119) and the shimming coil (120) comprises a number of tracks (121) on the printed circuit board (118) and a corresponding numbers of wires (122), with said number of tracks (121) being positioned between said two attachment points (119) and beneath said surface mounted device coil (117) and said number of wires (122) running across said surface mounted device coil (117).

10. A method of inductively measuring the bio-impedance of a conductive tissue (106), the method comprising the steps of:

- arranging a generator coil (101) and a separate sensor coil (108; 117), with the axis (109) of the sensor coil (108, 117) being orientated substantially perpendicular to the flux lines of a primary magnetic field (103) generated by means of the generator coil (101), said primary magnetic field (103) inducing an eddy current in the conductive tissue (106),

- sensing a secondary magnetic field by means of the sensor coil (108; 117), said secondary magnetic field being generated as a result of said eddy current, and

- generating a tertiary magnetic field by means of a shimming coil (113; 120) in a way that in the sensor coil (108; 117) the primary magnetic field (103) is cancelled out.

11. A computer program (115) for operating a system (100) for inductively measuring the bio-impedance of a conductive tissue (106), the system (100) comprising a generator coil (101) adapted for generating a primary magnetic field (103), said primary magnetic field (103) inducing an eddy current in the conductive tissue (106), a separate sensor coil (108; 117) adapted for sensing a secondary magnetic field, said secondary magnetic field being generated as a result of said eddy current, with the axis (109) of the sensor coil (108; 117) being orientated substantially perpendicular to the flux lines of the primary magnetic field (103), and a shimming coil (113; 120), the program (115) comprising computer instructions to automatically controlling the shimming coil (113; 120) to generate a tertiary magnetic field in a way that in the sensor coil (108; 117) the primary magnetic field (103) is cancelled out, when the computer program (115) is executed in a computer (114).

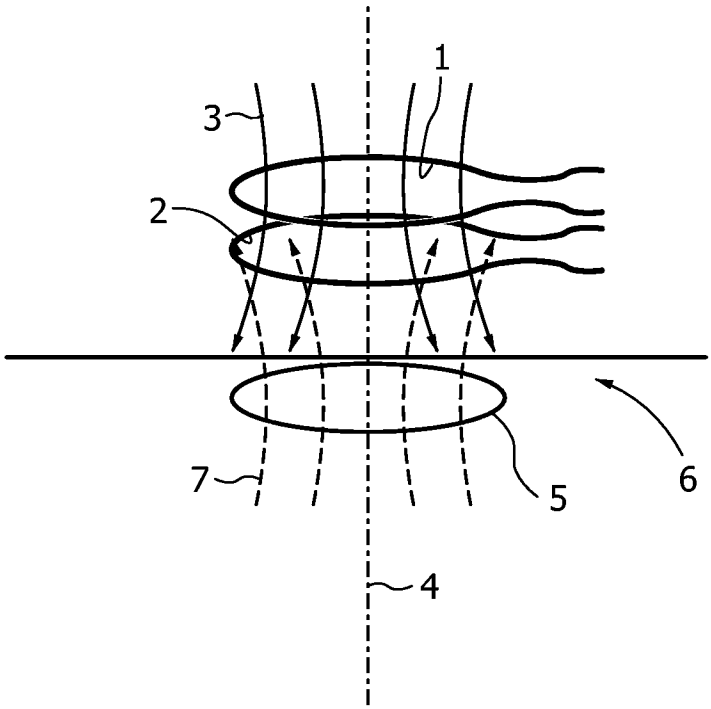

FIG. 1
PRIOR ART

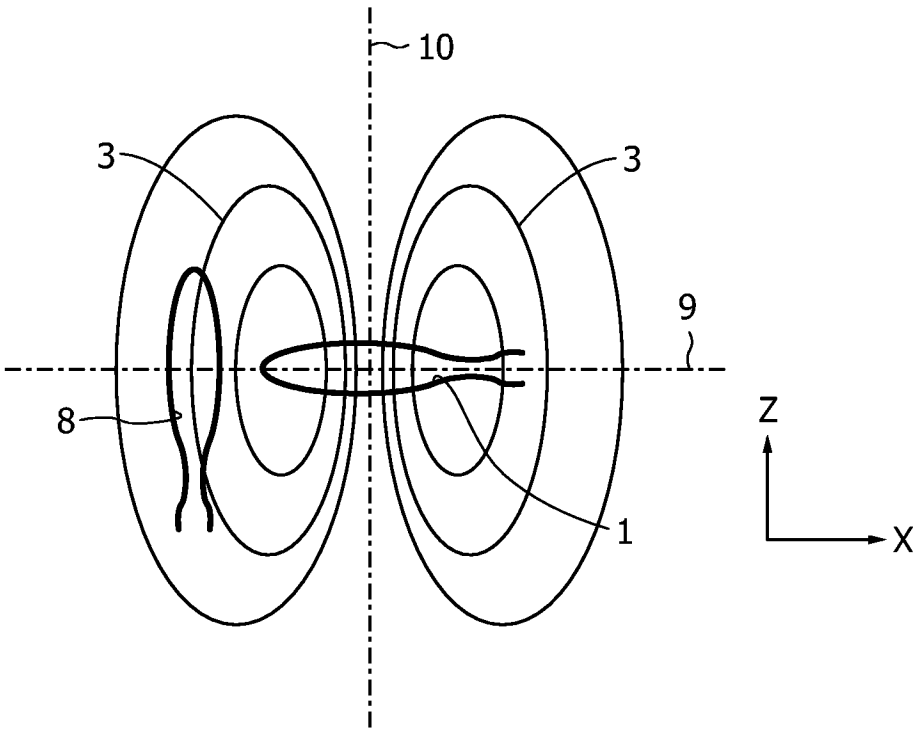

FIG. 2
PRIOR ART

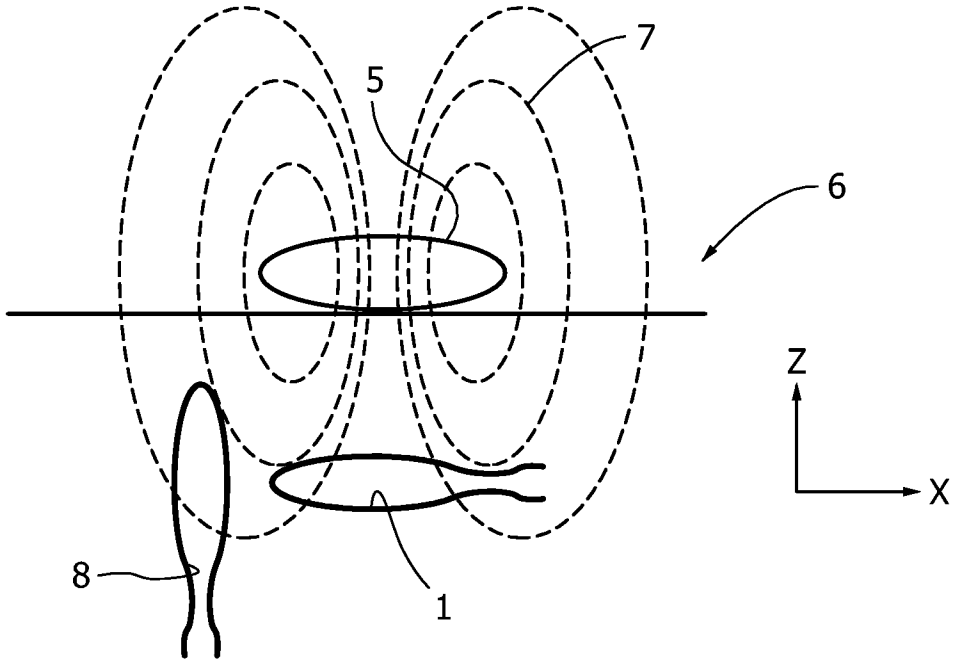

FIG. 3
PRIOR ART

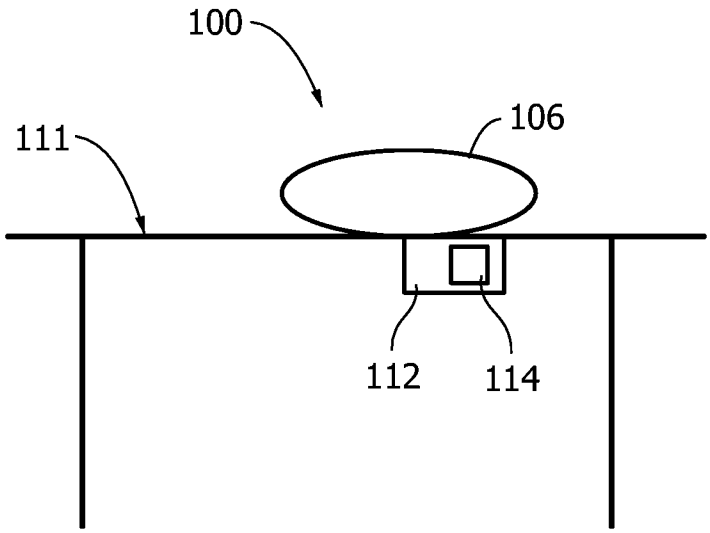

FIG. 4

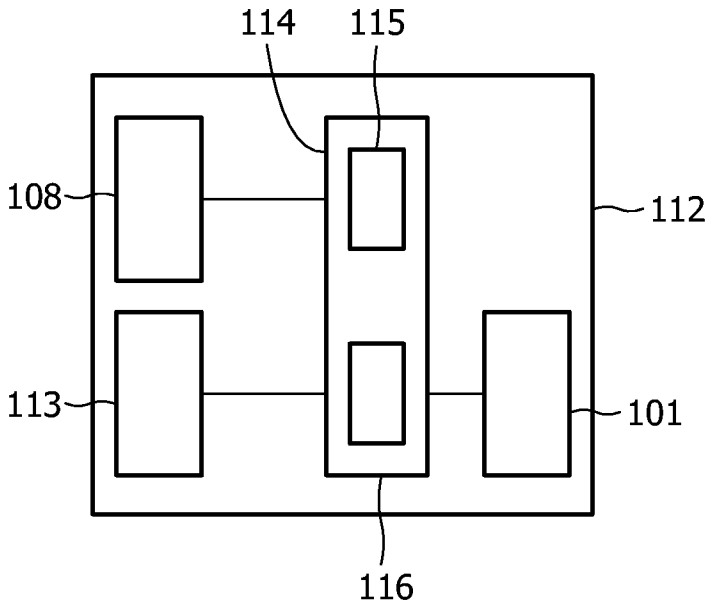

FIG. 5

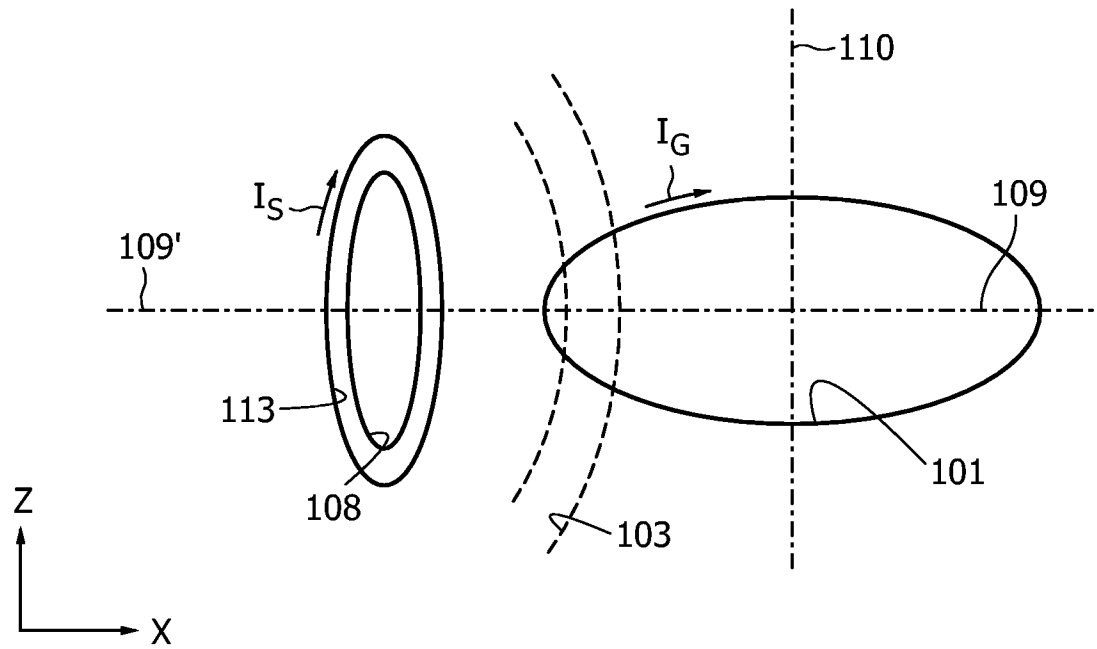

FIG. 6

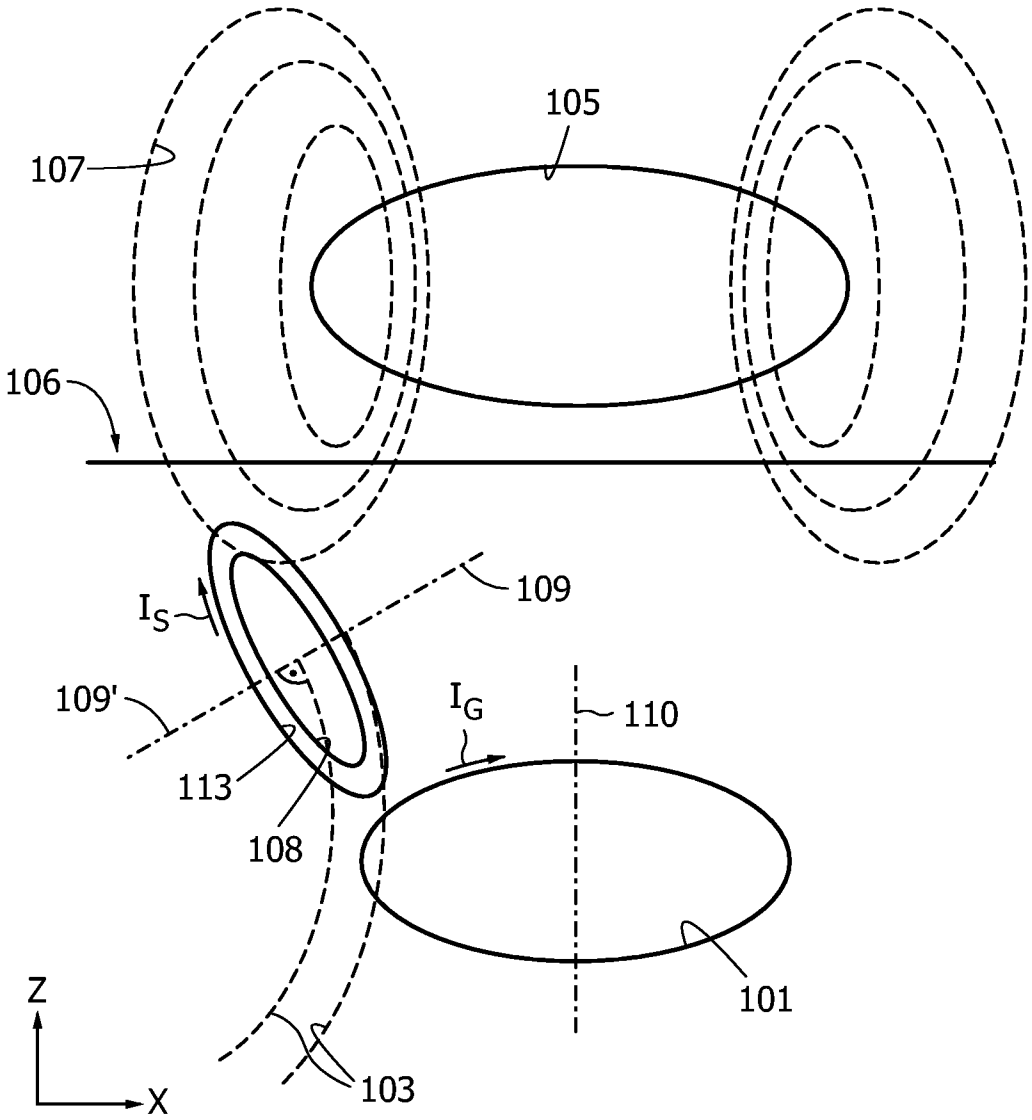
105
107
106
109
I_S
109'
I_G
110
113
108
101
Z
X
103

FIG. 7

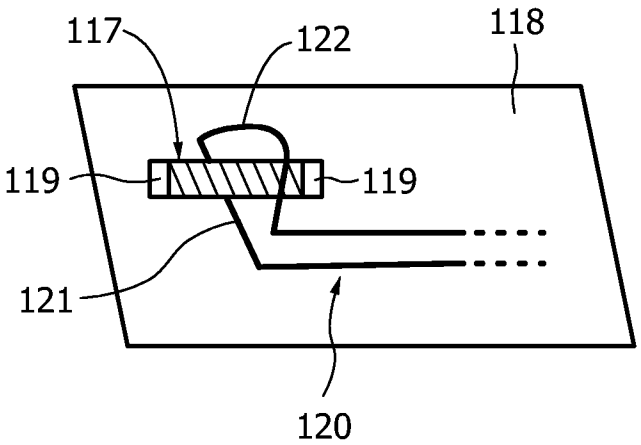
117
122
118
119
119
121
120

FIG. 8