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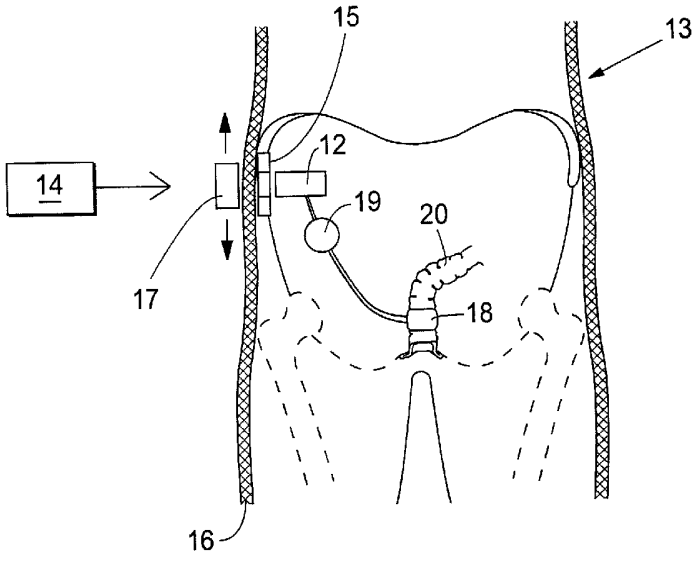
(54) **Title:** DETECTION OF IMPLANTED WIRELESS ENERGY RECEIVING DEVICE



(57) **Abstract:** An apparatus for detecting a wireless energy receiving device (12) that is subcutaneously implanted in a patient (13) is provided to enable accurate positioning of a wireless energy transmission device (14) outside the patient's body for transmission of wireless energy to the implanted energy receiving device. The apparatus includes a magnetic device (15) that emits a local magnetic field, and a magnetic detector (17) that detects the local magnetic field. The magnetic device (15) is subcutaneously implanted in the patient at the implanted energy receiving device (12) and the magnetic detector (17) is movable externally along the patient's body to establish a position at the patient's skin (16) where the local magnetic field is detected by the magnetic detector. As a result, the wireless energy transmission device (14) can be put in the established position, in order to efficiently transmit wireless energy to the implanted energy receiving device.

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DETECTION OF IMPLANTED WIRELESS ENERGY RECEIVING DEVICE

The present invention relates to an apparatus and method for detecting a wireless energy receiving device subcutaneously implanted in a patient to enable accurate positioning of an exterior wireless energy transmission device.

In new generations of energy consuming implants wireless energy transmission may be used for supply of energy to such implants. To optimise the transfer efficiency of the wireless energy it is important to locate the wireless energy receiver, typically subcutaneously implanted in the patient, in order to be able to put an exterior energy transmission device close to the implanted energy receiving device.

The object of the present invention is to provide an inexpensive apparatus for accurate detection of a wireless energy receiving device subcutaneously implanted in a patient, and further to provide an apparatus with parts to be implanted that are relatively small.

This object is obtained by an apparatus of the kind stated initially, comprising a magnetic device adapted to emit a local magnetic field, and a magnetic detector adapted to detect the local magnetic field emitted by the magnetic device. The magnetic device is designed to be subcutaneously implanted in the patient at the implanted energy receiving device, and the magnetic detector is movable externally along the patient's body to establish an energy transmission position at the patient's skin where the local magnetic field emitted by the magnetic device is detected by the magnetic detector. Alternatively, the magnetic detector is designed to be subcutaneously implanted and the magnetic device is movable along the patient's body to establish the energy transmission position at the patient's skin where the local magnetic field emitted by the magnetic device is detected by the magnetic

detector. As a result, the wireless energy transmission device can be put in the established energy transmission position, in order to efficiently transmit wireless energy to the implanted energy receiving device.

Thus, the present invention provides an easy way of detecting the position of the wireless energy receiving device subcutaneously implanted in a patient, which enables accurate positioning of the wireless energy transmission device outside the patient's body for efficient transmission of wireless energy to the implanted energy receiving device by using magnetism. Typical applications for such an energy receiving device are for energizing an implant in the patient, for example for treating reflux disease, obesity, anal or urinary incontinence, or impotence. The apparatus of the invention may conveniently be used for detecting an implanted energy receiving device coupled to such implants.

In accordance with a main first embodiment of the invention, the magnetic device is designed to be subcutaneously implanted in the patient at the implanted energy receiving device to emit the local magnetic field through a portion of the patient's skin adjacent to the energy receiving device, and the magnetic detector is movable externally along the patient's body to establish the energy transmission position where the local magnetic field is detected by the magnetic detector. Suitably, the magnetic detector is adapted to establish the energy transmission position at least substantially in front of the subcutaneously implanted energy receiving device to enable a most efficient energy transmission. The magnetic detector may be adapted to emit a sound when detecting the local magnetic field. Alternatively, the magnetic detector may be provided with at least one diode adapted to emit light when the detector detects the local magnetic field, or be provided with a

display adapted to indicate when the detector detects the local magnetic field.

In accordance with a second embodiment of the invention, the magnetic detector is designed to be subcutaneously implanted in the patient at the implanted energy receiving device, and the magnetic device is adapted to emit the local magnetic field through the patient's skin from outside the patient's body and is movable externally along the patient's body to establish the energy transmission position where the local magnetic field is detected by the implanted magnetic detector. Also in this second embodiment the magnetic device is suitably adapted to establish the energy transmission position at least substantially in front of the subcutaneously implanted energy receiving device. In its simplest form, the implanted magnetic detector may be adapted to emit a sound when detecting the local magnetic field. In a more sophisticated form, a sender may be implantable in the patient's body and be capable of sending information about the magnetic detector to outside the patient's body, as the magnetic detector detects the local magnetic field emitted by the magnetic device from outside the patient's body. For example, the implanted sender may send RF signals that inform when the implanted detector detects the local magnetic field, whereby an accurate energy transmission position at the patient's skin can be established. The accurate energy transmission position may be directly or indirectly correlated to the intensity of magnetism detected by the magnetic detector.

The magnetic device may be a solenoid or a permanent magnet, which is sending out a magnetic field.

In any of the above embodiments the magnetic detector includes a semiconductor circuit, preferably in the form of at least one Hall-element. By using one or more Hall-elements, a special type of semiconductor known in the art, it is easy to

locate the centre of the magnetic field emitted by the magnetic device. The magnetic detector suitably comprises several Hall-elements grouped around a central point in a triangular or square configuration. For example, three Hall-elements may be arranged at the corners of an equilateral triangle. An important advantage is that the Hall-elements are able to detect even a weak magnetic field emitted from the magnetic device.

The present invention also relates to a method of detecting a wireless energy receiving device subcutaneously implanted in a patient. The method comprises providing a magnetic device capable of emitting a local magnetic field through the patient's skin, providing a magnetic detector adapted to detect the local magnetic field emitted by the magnetic device, subcutaneously implanting the magnetic device or magnetic detector in the patient at the implanted energy receiving device, moving the magnetic detector or magnetic device externally along the patient's body, and establishing an energy transmission position at the patient's skin where the local magnetic field emitted by the magnetic device is detected by the magnetic detector. Then, the energy transmission device can be positioned in the established energy transmission position where the local magnetic field has been detected to efficiently transmit wireless energy to the subcutaneously implanted energy receiving device.

Where the magnetic detector is subcutaneously implanted and the magnetic device is moved along the patient's body, the method may further comprise implanting a sender and using the sender to send information to outside the patient's body confirming when the implanted magnetic detector detects the local magnetic field emitted by the exterior magnetic device.

The present invention also provides a surgical method for treating a patient having a disease, comprising the steps of: insufflating the patient's abdomen with gas; placing at least

two laparoscopic trocars in the patient's body; implanting an operable implant designed for treating reflux disease, urinary incontinence, impotence, anal incontinence or obesity in the abdomen by using surgical instruments through the trocars; subcutaneously implanting a wireless energy receiving device for supplying energy for use in the operation of the implant and a magnetic device at the energy receiving device for emitting a local magnetic field through the adjacent skin portion of the patient; post-operatively moving an exterior magnetic detector along the patient's body to establish an energy transmission position in which the local magnetic field emitted by the implanted magnetic device is detected by the magnetic detector; bringing a wireless energy transmission device to the established energy transmission position; and transmitting wireless energy from the wireless energy transmission device through the patient's skin to the implanted wireless energy receiving device.

As an alternative, the surgical method may comprise subcutaneously implanting a magnetic detector at the energy receiving device and post-operatively moving an exterior magnetic device emitting a local magnetic field along the patient's body to establish the energy transmission position in which the local magnetic field emitted by the exterior magnetic device is detected by the implanted magnetic detector.

The skilled person should appreciate that the detection technique described above is simple, inexpensive and very accurate, and could be used for several different implants in combination with wireless energy transmission.

The invention is described in more detail in the following with reference to the accompanying drawings, in which

Fig.1 shows a connection diagram for a magnetic detector of the apparatus according to the present invention,

Fig.2 schematically illustrates in a diagram the output of the magnetic detector positioned in front of a magnetic device of the apparatus of the invention,

Fig. 3 is a schematic view of an embodiment where the magnetic device is subcutaneously implanted in a patient, and the magnetic detector is movable externally along the patient's body,

Fig. 4 is a schematic view of an embodiment where the magnetic detector is subcutaneously implanted in the patient and the magnetic device is movable externally along the patient's body,

Fig. 5 is a schematic view of a hydraulically adjustable constriction device designed for treating reflux disease, urine incontinence, anal incontinence or obesity, and

Fig. 6 illustrates an embodiment according to the present invention using Hall-elements as the magnetic detecting device.

Referring to the drawing figures, like reference numerals designate identical or corresponding elements throughout the several figures.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a connection circuit 1 for a magnetic detector 2 of the apparatus according to the present invention. A magnetic device in the form of a ring-magnet 3, which can be a solenoid or a permanent magnet, is implanted in a patient's body. Located outside the body and positioned in front of the implanted ring-magnet 3 is magnetic detector 2, which includes three linear magnetic field sensors 4 (such as Hall-elements or the like) grouped in a triangular configuration. Sensors 4 are connected to signal-conditioning amplifiers 5, which in turn, are connected to an A/D-converter 6. A microprocessor 7 is connected to A/D-converter 6. To

visually display the output signals of sensors 4, a display-device 8 is connected to microprocessor 7.

The graph shown in Fig. 2 illustrates, in principle, how the information obtained by detector 2 can be presented. On the X-axis in the graph is the position of detector 2 relative to the magnetic device. On the Y-axis is the combined output of sensors 4 of detector 2. Thus, the graph of Fig. 2 shows the position "X" of detector 2 relative to the magnetic device as a function of detector 2's output "Y". To illustrate this method of detecting, a magnetic device in the form of a ring-magnet 9 is shown relative to the graph of Figure 2. Ring-magnet 9 is shown in cross-section to show the positions of its magnetic north pole N and south pole S, respectively. Fig. 2 depicts the case where magnetic detector 2 (not shown in Fig. 2) has been centred in front of ring-magnet 9 and where all of the sensors 4 produce a maximum output, which is shown as peaks 10,11 in the graph of Fig. 2. Sensors 4 are connected (*e.g.*, by connection circuit 1 shown in Fig. 1) to display device 8, which may display the graph shown in Fig. 2, or alternatively, a numeral result from the measurements taken by sensors 4.

Fig. 3 shows an embodiment of the apparatus of the present invention for detecting a wireless energy receiving device 12 subcutaneously implanted in a patient 13 suffering from anal incontinence to enable accurate positioning of a separate wireless energy transmission device 14 outside patient 13's body for the transmission of wireless energy to energy receiving device 12. An operation device 19 is adapted to operate an implanted artificial sphincter 18 applied to the patient's rectum 20. Energy receiving device 12 powers operation device 19 with energy received from the energy transmission device 14. The implanted energy receiving device 12 may be of the type that transforms the received energy into electrical pulses. In this case, a sender may be implanted in

the patient for sending feedback information on the number of electrical pulses that have been provided by the energy receiving device. The apparatus also includes a magnetic device 15 subcutaneously implanted in patient 13 close to the energy receiving device 12. Magnetic device 15 emits a local magnetic field extending through a portion of patient 13's skin 16 adjacent to energy receiving device 12. The apparatus further includes an external, separate magnetic detector 17 that may be manually moved along the patient 13's body to establish an energy transmission position at the patient's skin where the local magnetic field emitted by magnetic device 15 is detected by magnetic detector 17. When this energy transmission position has been established, energy transmission device 14 can be located in the same position to efficiently transmit wireless energy to implanted energy receiving device 12.

Fig. 4 shows an embodiment of the invention identical to the embodiment according to Fig. 3, except that a magnetic detector 21 is subcutaneously implanted in patient 13 at energy receiving device 12 and an external separate magnetic device 22 that emits a local magnetic field through patient's 13 skin 16 is provided. Magnetic device 22 may be manually moved externally along the patient 13's body to establish an energy transmission position at the patient's skin where the local magnetic field emitted by magnetic device 22 is detected by the implanted magnetic detector 21. A sender 23 is implanted in patient 13 and sends information about the status of magnetic detector 21. Thus, when magnetic detector 21 detects the local magnetic field emitted by external magnetic device 22, sender 23 sends information confirming that magnetic device 22 is in a proper position for energy transmission. When this energy transmission position has been established, energy transmission device 14 can be placed in

the same position to efficiently transmit wireless energy to the implanted energy receiving device 12.

Fig. 5 shows an example of the artificial sphincter 18 shown in Figs. 3 and 4. Sphincter 18 includes a hydraulically adjustable constriction device 24 to be applied around the patient's rectum (not shown in Fig. 5). Constriction device 24 has a cavity 25 which can be inflated by supplying hydraulic fluid thereto, to close the rectum, and be deflated by withdrawing hydraulic fluid therefrom, to open the rectum. A hydraulic operation device 26 for operating constriction device 24 is powered with energy from implanted energy receiving device 12. This type of constriction device may also be used as an artificial sphincter for treating patient's suffering from heartburn and reflux disease or urinary incontinence, when combined with the apparatus of the present invention. Furthermore, constriction device 24 may be used for forming an adjustable stoma opening in the stomach or esophagus of an obese patient to treat obesity or for restricting the penile exit blood flow to treat an impotent patient, when combined with the apparatus of the invention.

Fig. 6 shows an advantageous design of the embodiment shown in Fig. 3, in which the external magnetic detector 17 includes three symmetrically arranged Hall-elements 27 which are grouped around a central point in a triangular configuration. The magnetic device 15 is implanted and includes a ring-shaped magnet 28 surrounding the centre 29 of the implanted energy receiving device 12. When magnetic detector 17 is moved to a position in which Hall-elements 27 are placed symmetrically above and around ring-shaped magnet 28, as illustrated in Fig. 6, magnetic detector 17 detects a maximum intensity of the magnetic field emitted by the implanted magnet 28, whereby the most accurate position where the energy transmission device 14 should be placed is established. As an alternative, the design described above may

be practised in the embodiment shown in Fig. 4. Thus, the implanted magnetic detector 21 may include the three Hall-elements 27 and the external magnetic device 22 may include the ring-shaped magnet 28.

Although the present invention has been described in terms of a particular embodiment and process, it is not intended that the invention be limited to that embodiment. Modifications of the embodiment and process within the spirit of the invention will be apparent to those skilled in the art. The scope of the invention is defined by the claims that follow.

CLAIMS

1. An apparatus for detecting a wireless energy receiving device (12) adapted to be subcutaneously implanted in a patient (13) to enable accurate positioning of a wireless energy transmission device (14) outside the patient's body for transmission of wireless energy to the implanted energy receiving device, the apparatus comprising:

a magnetic device (15;22) adapted to emit a local magnetic field, and

a magnetic detector (17;21) adapted to detect the local magnetic field emitted by the magnetic device,

wherein the magnetic device (15) or magnetic detector (21) is designed to be subcutaneously implanted in the patient at the implanted energy receiving device (12), and the magnetic detector (17) or magnetic device (22) is movable externally along the patient's body to establish an energy transmission position at the patient's skin (16) where the local magnetic field emitted by the magnetic device is detected by the magnetic detector, whereby the wireless energy transmission device (14) can be put in the established energy transmission position, in order to efficiently transmit wireless energy to the implanted energy receiving device.

2. An apparatus according to claim 1, wherein the magnetic device (15) is designed to be subcutaneously implanted in the patient at the implanted energy receiving device (12) to emit the local magnetic field through a portion of the patient's skin (16) adjacent to the energy receiving device, and the magnetic detector (17) is movable externally along the patient's body to establish the energy transmission position where the local magnetic field is detected by the magnetic detector.

3. An apparatus according to claim 2, wherein the magnetic detector is adapted to establish the energy

transmission position at least substantially in front of the subcutaneously implanted energy receiving device.

4. An apparatus according to claim 1, wherein the magnetic detector (21) is designed to be subcutaneously implanted in the patient at the implanted energy receiving device (12), and the magnetic device (22) is adapted to emit the local magnetic field through the patient's skin (16) from outside the patient's body and is movable externally along the patient's body to establish the energy transmission position where the local magnetic field is detected by the implanted magnetic detector.

5. An apparatus according to claim 4, wherein the magnetic device is adapted to establish the energy transmission position at least substantially in front of the subcutaneously implanted energy receiving device.

6. An apparatus according to claim 4 or 5, further comprising a sender (23) implantable in the patient's body and capable of sending information about the magnetic detector (21) to outside the patient's body, as the magnetic detector detects the local magnetic field emitted by the magnetic device (22) from outside the patient's body.

7. An apparatus according to any one of claims 1-6, wherein the magnetic detector is adapted to emit a sound when detecting the local magnetic field.

8. An apparatus according to claim 2 or 3, wherein the magnetic detector is provided with at least one diode adapted to emit light when the detector detects the local magnetic field.

9. An apparatus according to claim 2 or 3, wherein the magnetic detector is provided with a display adapted to indicate when the detector detects the local magnetic field.

10. An apparatus according to any one of claims 1-9, wherein the magnetic device (15;22) is a solenoid or a permanent magnet.

11. An apparatus according to any one of claims 1-10, wherein the magnetic detector comprises a semiconductor circuit.

12. An apparatus according to claim 11, wherein the semiconductor circuit of the magnetic detector comprises at least one Hall-element (27).

13. An apparatus according to claim 12, wherein the magnetic detector (17;21) comprises several Hall-elements (27) grouped around a central point in a triangular or square-configuration.

14. Use of the apparatus according to any one of claims 1-13 for detecting a wireless energy receiving device, which is subcutaneously implanted in a patient and which energizes an implant in the patient for treating reflux disease, obesity, anal or urinary incontinence, or impotence.

15. A method of detecting a wireless energy receiving device (12) subcutaneously implanted in a patient, the method comprising:

providing a magnetic device (15;22) capable of emitting a local magnetic field through the patient's skin (16),

providing a magnetic detector (17;21) adapted to detect the local magnetic field emitted by the magnetic device,

subcutaneously implanting the magnetic device (15) or magnetic detector (21) in the patient at the implanted energy receiving device (12),

moving the magnetic detector (17) or magnetic device (22) externally along the patient's body, and

establishing an energy transmission position at the patient's skin (16) where the local magnetic field emitted by the magnetic device is detected by the magnetic detector.

16. A method according to claim 15, wherein the magnetic detector (21) is subcutaneously implanted and the magnetic device (22) is moved along the patient's body, further

comprising implanting a sender (23) and using the sender to send information to outside the patient's body confirming when the implanted magnetic detector detects the local magnetic field emitted by the exterior magnetic device (22).

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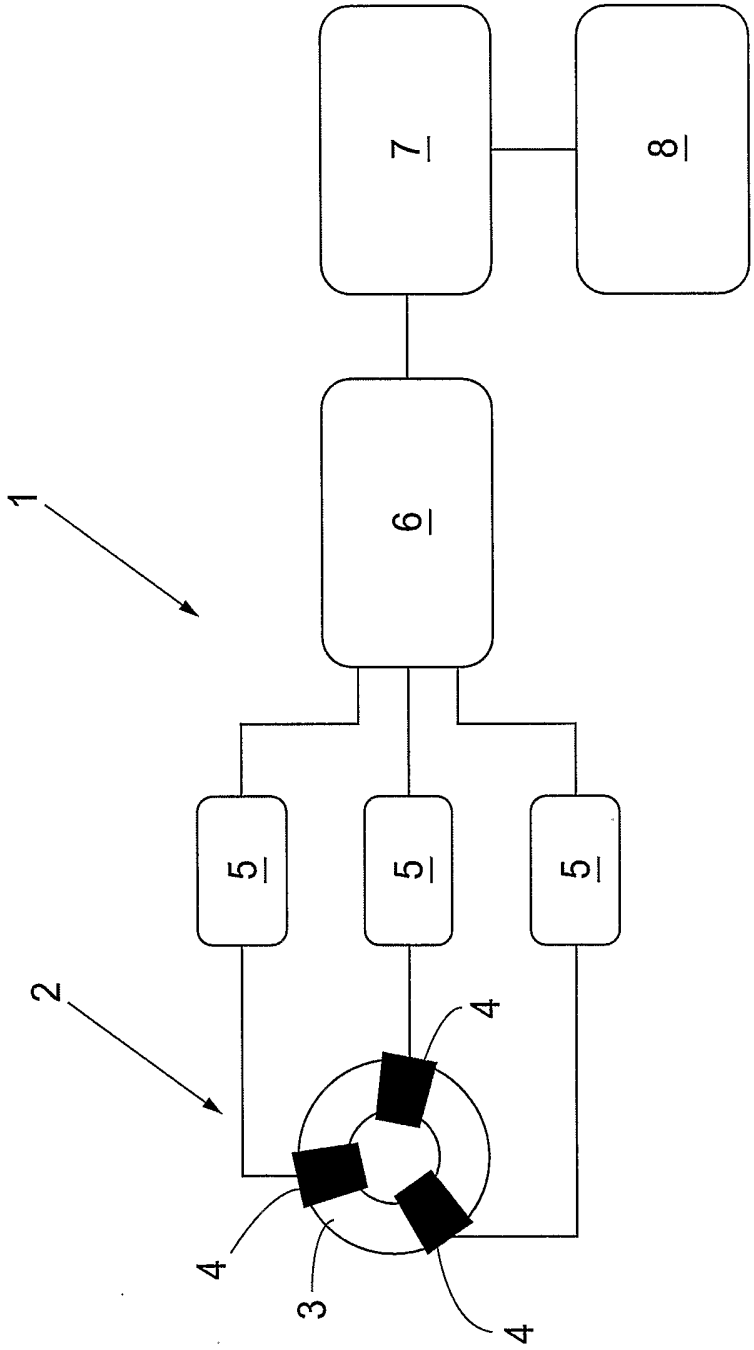

Fig. 1

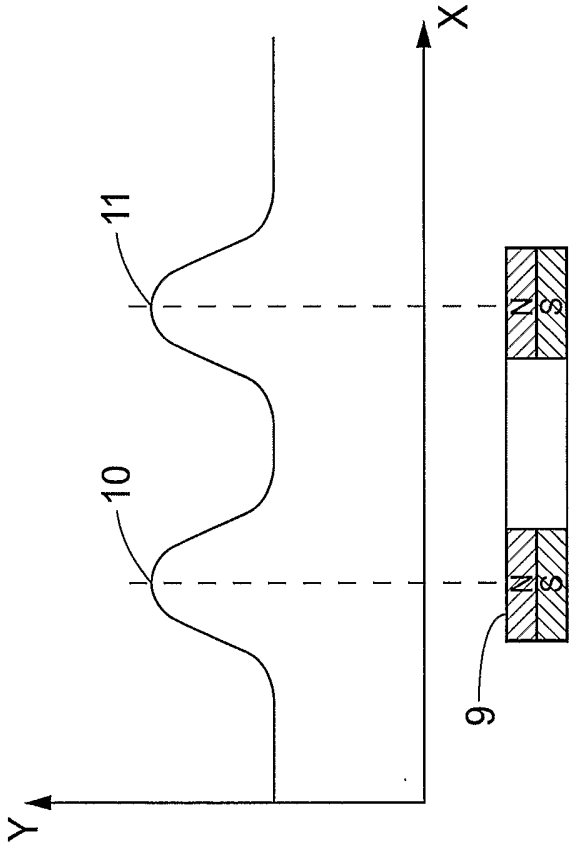

Fig. 2

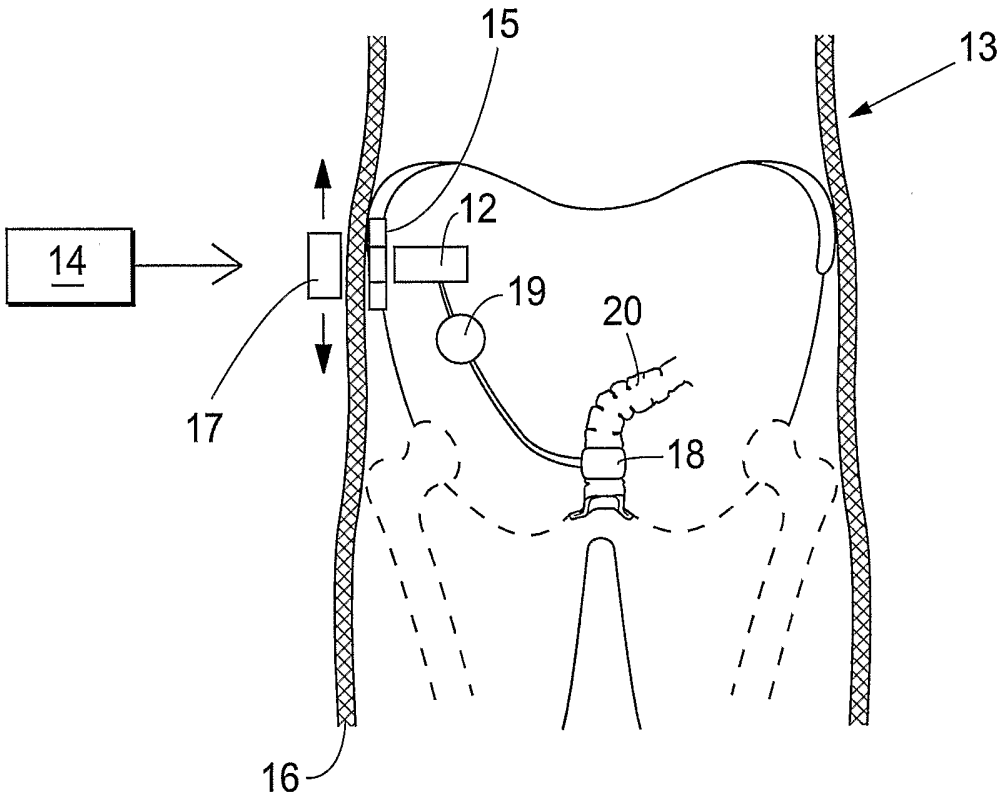

Fig. 3

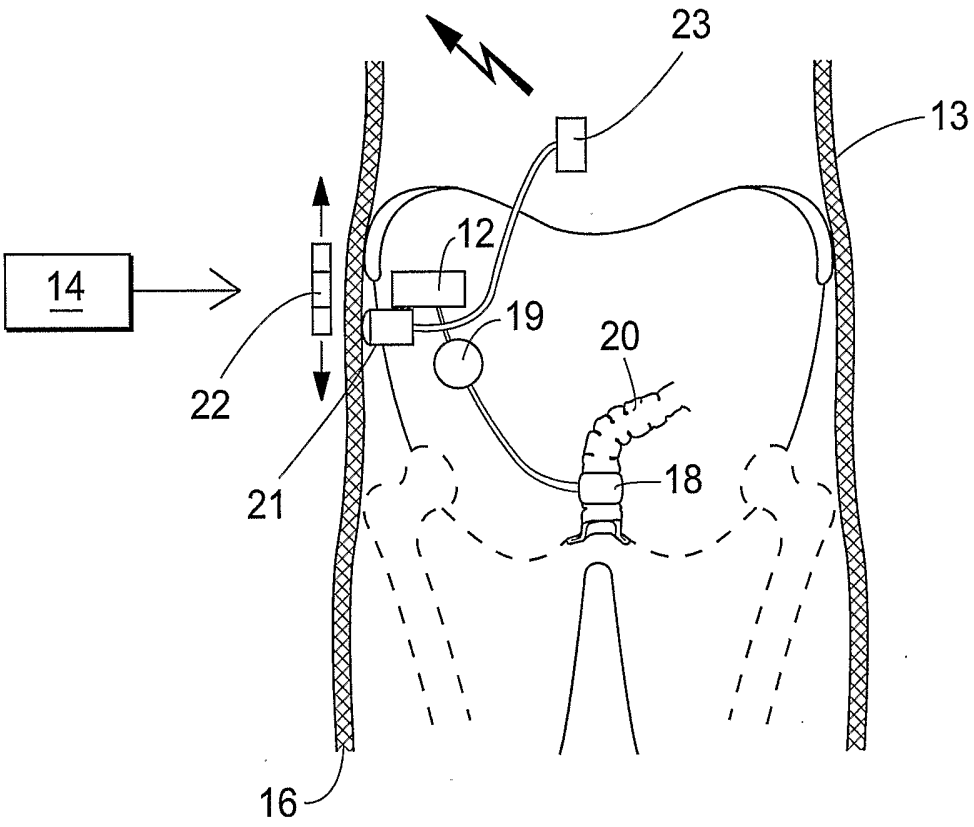

Fig. 4

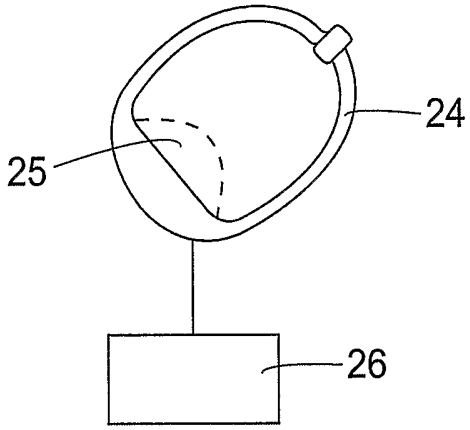

Fig. 5

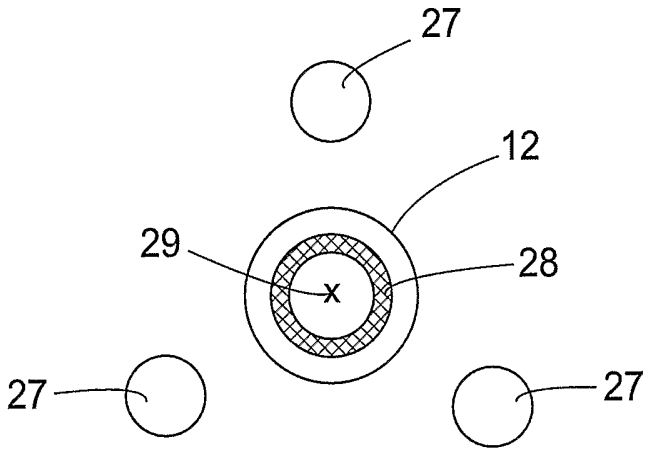

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 03/01458

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: A61N 1/08 // A61N 1/378
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5314453 A (JEUTTER, D.C.), 24 May 1994 (24.05.94), column 1, line 5 - column 2, line 2; column 3, line 1 - line 8; column 3, line 16 - line 25, column 4, line 12 - line 17; column 5, line 1 - line 40; figures 1-2,5; abstract --	1-16
A	US 5630836 A (PREM, E.K. ET AL), 20 May 1997 (20.05.97), abstract --	6
A	US 6088619 A (HEIN, W. ET AL), 11 July 2000 (11.07.00), column 3, line 32 - line 43, abstract --	7-9

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 November 2003	05 -12- 2003
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Åsa Rydenius /OGU Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 03/01458

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 0137926 A1 (ABIOMED, INC.), 31 May 2001 (31.05.01), claim 58, abstract --	1-16
P,X	US 6473652 B1 (SARWAL, A. ET AL), 29 October 2002 (29.10.02) -- --------	1-16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 03/01458

Box I **Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: **14-16**
because they relate to subject matter not required to be searched by this Authority, namely:

see extra sheet

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II **Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

The method of claims 14-16 comprises in-vivo surgery and measurements performed on a patient in order to implant an energy receiving device and to locate said device. As the method includes the step of surgery and scanning of a body part, this necessarily requires medically skilled staff and the method is to be carried out under the responsibility of a doctor. Thus, the International Search Authority is not required to carry out an international search for these claims (Rule 39.1(iv)). Nevertheless a search was conducted with these claims in mind but with the focus on the physical device.

INTERNATIONAL SEARCH REPORT

Information on patent family members

06/09/03

International application No.
PCT/SE 03/01458

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5314453 A	24/05/94	NONE	
US 5630836 A	20/05/97	CA 2167342 A,C	20/07/96
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		GB 9600945 D	00/00/00
		NL 1002130 A,C	00/00/00
US 6088619 A	11/07/00	DE 19908438 A,C	21/09/00
		EP 1032109 A	30/08/00
WO 0137926 A1	31/05/01	EP 1231981 A	21/08/02
US 6473652 B1	29/10/02	NONE	